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*Roadside hawkers in India (S. Uma, NR*CB)

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Editorial Office:
INFO*MUSA,* INIBAP,
Parc Scientifique Agropolis II,
34397 Montpellier Cedex 5, France.
Telephone + 33-(0)4 67 61 13 02;
Telefax: + 33-(0)4 67 61 03 34;
E-mail: inibap@cgiar.org

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The mission of the International Network for the Improvement of Banana and Plantain is to sustainably increase the productivity of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

The Programme has four specific objectives:

- To organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved cultivars and at the conservation and use of *Musa* diversity
- To promote and strengthen collaboration and partnerships in banana-related research activities at the national, regional and global levels
- To strengthen the ability of NARS to conduct research and development activities on bananas and plantains
- To coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a Future Harvest Centre.

CONTENTS

Survey of banana endophytic fungi from Central America and screening for biological control of the burrowing nematode (*Radopholus similis)*

L. Pocasangre, R.A. Sikora, V. Vilich and R.P. Schuster

Fungi that colonise healthy plant tissue and either persist there in a dormant phase or initiate more extensive but symptomless infections are known as endophytes (Carroll 1988, Boddy and Griffith 1989, Yates *et al*. 1997). When the colonisation leads to a protection of the tissue against biotic and/or abiotic stress, these fungi are called mutualistic (Carroll 1990, Latch 1993).

A survey of endophytic fungi was carried out in Central America during January to February 1997. The surveyed countries were Honduras, Costa Rica, Guatemala and Cuba in the Caribbean. Eight banana plantations were sampled in the region. Twenty-one different *Musa* spp. cultivars were sampled, including dessert banana, cooking banana and plantain belonging to seven different *Musa* genomes: AA, AB, AAA, AAB, ABB, AAAB and AABB.

The burrowing nematode *Radopholus similis* (Cobb) Thorne is the most important nematode species in banana and plantain production in Central America, West Africa and Australia (Pinochet 1986, Sarah 1989, Schipke and Ramsey 1994). Conventional planting material (suckers) is mainly responsible for the dispersion of nematodes into new banana plantations. The use of tissue culture plantlets provides pest free planting material. However it is well known that tissue culture plantlets are more susceptible to nematodes and *Fusarium* wilt than suckers (Musanews 1997, Smith *et al*. 1998). This susceptibility of tissue culture plantlets may be caused by the fact that the plantlets are produced under aseptic conditions and are free of mutualistic fungi, which could increase root health status of these plants.

The purpose of this investigation was to study the natural incidence of endophytic fungi on healthy plants of different banana cultivars in Central America and determine the effect of these fungi on the rate of reproduction of *R. similis* in inoculated and noninoculated tissue culture plantlets on four commercial banana cultivars.

Material and methods

Countries surveyed in Central America

Root and corm tissue samples were collected from eight banana plantations from three countries in Central America: Costa Rica (CATIE, Turrialba and EARTH, Guacimo), Guatemala (Tiquizate, Molina group plantation), Honduras (FHIA, La Lima, El Rosario and La Ceiba, Dole plantations) and Cuba (Remedios and Antillas, IBP experimental stations).

The banana cultivars surveyed were selected according to their commercial importance for fruit exportation and for local consumption in the region. All banana plantations surveyed have been planted with banana as a monocrop for more than 15 years.

Isolation of endophytic fungi

The isolation of endophytic fungi was carried out from the roots and corm using the protocol showed in the Figure 1. Primary roots were split into two longitudinal sections and placed in a 5% sodium hypochlorite solution for five minutes and washed with sterile tap water three times. The root sections were placed on autoclaved paper towelling to remove excess water and the outer layer of root was then peeled off with a scalpel. The remaining internal tissue was cut into small pieces of approximately 1 to 1.5 cm length with a heat sterilized knife. These small pieces were placed on potato dextrose agar 10% strength (PDA 10%) containing 150 ppm Streptomycin and Penicillin. The cultures were incubated at 25°C in the dark and the fungi were transferred to new plates for testing and identification one week later.

The isolation of endophytic fungi from the corm was done from the outer cortex and central cylinder. The corms were split in two longitudinal sections and small blocks of approximately 0.5-1.0 cm length were cut from tissue and sterilized as described above. The fungal isolation was done using the protocol described for roots.

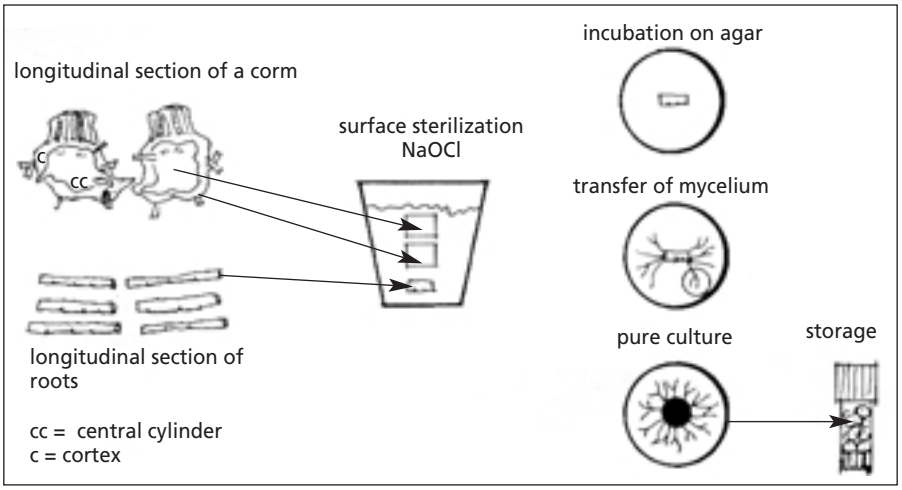

***Figure 1**. Sterilization and isolation protocol used for detection of endophytic fungi from roots and corm tissue.*

Plant materials

Tissue culture plantlets of Gran Enano (AAA), Williams (AAA), Gros Michel (AAA) and FHIA-23 (AAAA) were produced using the propagation method of Wong (1986). The plantlets were obtained using lateral shoot tips and inoculated on medium containing MS Salts (Murashige and Skoog, 1962). The MS medium was supplemented with 30g/l of Sucrose, 2.5mg/l of Benzylaminopurine BAP and 0.5mg/l of Indolacetic acid IAA. The incubation conditions were 25±2 °C and 16 hours daylength.

Inoculation and *in vivo* screening of endophytic fungi

Conidial suspensions of endophytic fungi were obtained by using Sun and

Su's technique (1984). Cultures of endophytic fungi from seven-day-old grown on potato dextrose agar were filtered through two layers of Cheesecloth. The conidial suspension was adjusted to 1.2 x 10^6 cfu/ml by supplementing Ringer solution. The roots of plantlets about 12 cm tall were immersed in conidial suspension for five minutes before replanting in 650 cm^3 pots with sterilised sand. The control plantlets were treated with Ringer solution without endophytic fungi. The plantlets were reinoculated with endophytic fungi after two weeks of the first inoculation. Reinoculation was made around the roots of each plant by pipetting 5ml spores suspension in three holes at the base of the pseudostem. Twenty-eight endophytic fungi isolated from banana roots in Central America and Africa were screened for antagonistic activity to *R. similis* on the cultivar Gran Enano. The most effective endophytic isolates were retested on four banana cultivars and were also used for more detailed studies.

Source of nematodes and inoculation procedures

Nematode inoculum consisted of a population of *R. similis* isolated from the cultivar Valery in Talamanca, Costa Rica. The nematodes were increased in monoxenic culture on carrot discs (O'Bannon and Taylor 1968). One month after the inoculation with endophytic fungi, the plantlets were inoculated with 500 nematodes per pot. Application was made around the roots of each plant by pipetting the nematode suspension into three holes at the base of the pseudostem.

Two months after inoculation, nematode densities were determined in root system and soil. Nematodes in the root system were obtained by cutting free the whole root system from the plantlets. The root system was stained in a 0.1% acid-Fuchsin solution and macerated in a blender for 15s. Nematodes in two 10-ml aliquots were counted and the total number of nematodes per root system was calculated. Nematodes in the soil were obtained by removing a sample of 200g of sand from the pot and placing it on a modified Baermann dish. After two days, nematodes were collected and concentrated on a 25µm sieve. The total number of nematodes per pot was determined by calculations based on nematode counts in a 10ml aliquot of the total solution.

Statistical analysis

The experimental design used for all trials was a completely randomised block design. All data were analysed by analysis of variance (PROC ANOVA, SAS Version 6.12 for Windows, SAS Institute, Cary, USA). Nematode counts were transformed before statistical analysis using ln (x + 1). Means were compared by Duncan's multiple range test ($P \leq 0.05$).

Table 1. Number of endophytic fungi isolated from different tissue of 21 banana cultivars in Central America.

Country	Roots	Cortex	Central Cylinder	Total
Honduras	22	14	8	44
Guatemala	9	6	1	16
Costa Rica	15	4	2	21
Cuba	43	6	2	51
	89 (67,5 %)	30 (22,7 %)	13 (9,8 %)	132 (100 %)

Values in% are the frequency of occurrence of the fungi per banana tissue.

Table 2. Origin of identified endophytic fungi isolated from different banana cultivars in Central America

Fungus code	*Fungus genus*	Cultivar/Genome	Tissue	Place
Honduras (H)				
H-06	*Fusarium* spp.	Giant Cavendish (AAA)	central cylinder	FHIA collection
H-07	*Fusarium* spp.	Lacatan (AAA)	roots	FHIA collection
H-12	*Fusarium* spp.	Cavendish (AAA)	roots	FHIA collection
H-14*	*Fusarium* spp.	Cavendish (AAA)	roots	FHIA collection
H-15	*Trichoderma* sp.	Cavendish (AAA)	central cylinder	FHIA collection
H-19*	*Fusarium* spp.	Bluggoe (ABB)	roots	FHIA collection
H-20*	*Fusarium* spp.	Dwarf Cavendish (AAA)	roots	FHIA collection
H-26*	*Fusarium* spp.	Ney Poovan (AB)	roots	FHIA collection
H-31	*Verticillium* spp.	P.J. Buaya (AA)	cortex	FHIA collection
H-35	*Fusarium* spp.	Gran Enano (AAA)	roots	Dole, Rosario
H-36	*Fusarium* spp.	Gran Enano (AAA)	cortex	Dole, Rosario
H-37	*Acremonium* spp.	Gran Enano (AAA)	cortex	Dole, Rosario
H-39	*Fusarium* spp.	Gran Enano (AAA)	roots	Dole, La Ceiba
H-42	*Fusarium* spp.	Gran Enano (AAA)	cortex	Dole, La Ceiba
H-43	*Fusarium* spp.	Gran Enano (AAA)	cortex	Dole, La Ceiba
Costa Rica (CR)				
CR-01	*Fusarium* spp.	Gran Enano (AAA)	roots	CATIE, Turrialba
CR-04	*Fusarium* spp.	Gran Enano (AAA)	roots	CATIE, Turrialba
CR-09	*Fusarium* spp.	Gran Enano (AAA)	roots	EARTH, Guacimo
CR-10	*Fusarium* spp.	Gran Enano (AAA)	roots	EARTH, Guacimo
CR-19	*Fusarium* spp.	Gran Enano (AAA)	cortex	EARTH, Guacimo
CR-21	*Acremonium* spp.	Gran Enano (AAA)	cortex	EARTH, Guacimo
Guatemala (G)				
G-01	*Fusarium* spp.	Gran Enano (AAA)	roots	Tiquizate
G-05	*Verticillium* spp.	Gran Enano (AAA)	roots	Tiquizate
G-08	*Fusarium* spp.	Gran Enano (AAA)	cortex	Tiquizate
G-11	*Fusarium* spp.	Gran Enano (AAA)	cortex	Tiquizate
G-12	*Fusarium* spp.	Gran Enano (AAA)	cortex	Tiquizate
Cuba (C)				
C-03	*Fusarium* spp.	FHIA-01 (AAAB)	roots	IBP, Remedios
C-09	*Fusarium* spp.	FHIA-03 (AABB)	roots	IBP, Antillas
C-13*	*Fusarium* spp.	FHIA-03 (AABB)	roots	IBP, Antillas
C-20	*Fusarium* spp.	FHIA-03 (AABB)	roots	IBP, Remedios
C-22	*Fusarium* spp.	FHIA-03 (AABB)	roots	IBP, Remedios
C-35	*Fusarium* spp.	FHIA-21 (AAAB)	roots	IBP, Remedios
C-39	*Fusarium* spp.	Gros Michel (AAA)	roots	IBP, Remedios
C-48	*Fusarium* spp.	FHIA-21 (AAAB)	roots	IBP, Remedios
C-49	*Fusarium* spp.	FHIA-21 (AAAB)	roots	IBP, Remedios

* Effective endophytic fungi, which caused reduction in the number of *R. similis*/g root higher than 80% in relation to control.

Results

A total of 132 endophytic fungi were recovered from the 120 tissue samples of the roots and corms in the region. The frequency of occurrence of endophytic fungi was higher in the roots than in the cortex and central cylinder of the corm (Table 1).

Fusarium spp. were the predominant endophytic fungus in all countries surveyed and was found in all localities studied. The frequency of occurrence of *Fusarium* spp. was higher in the roots than in the cortex and central cylinder of the corm (Table 2).

Different degrees of activity toward *R. similis* were found among the endophytic isolates. Three isolates

caused a reduction in the number of *R. similis*/g root higher than 90% on the cultivar Gran Enano and only nine of 28 isolates were considered less active with a reduction lower than 30% (Table 3). The most effective endophytic isolates: H-14, H-19, H-20, H-26 and C-13 were retested on four banana cultivars: Gran Enano, Williams, Gros Michel and FHIA-23 and the fungi were able to cause reductions in the number of *R. similis*/g root higher than 80% on all banana cultivars (data not shown). These effective endophytic isolates were also used for more detailed studies that are not included in this publication.

Table 3. Classes of activity of 28 *Fusarium* spp. isolates on the reproduction rate of *Radopholus similis* on the cultivar Gran Enano (AAA).

Classes of activity	Number of isolates	% of isolates
negative effect	2	7
< 30 %	7	25
30-50 %	3	11
50-70 %	5	18
71-90 %	8	28
> 90 %	3	11
Total	**28**	**100**

Values in percentages are the reduction in the number of *R. similis* in relation to control plantlets.

Discussion

The results of this survey demonstrated that the frequency of occurrence of endophytic fungi was higher in the roots than in the cortex and central cylinder of the corm of commercial banana cultivars. From 132 fungi isolated, 89 were isolated from the roots, 30 from the cortex and 13 from the central cylinder of the corm.

Fusarium spp. are found in banana as natural endophytes and have been detected in the roots of different banana cultivars in several countries (Speijer 1993, Amin 1994, Schuster *et al*. 1995). The results of this survey demonstrated that the most frequently found endophytic fungi isolated were strains of *Fusarium*. The fungi were found in the eight localities sampled in Central America and Cuba in the Caribbean. Strains of *Fusarium* spp. were isolated from different banana cultivars, including dessert, cooking and plantain belonging to diploids, triploids and tetraploids genomes. These results suggest that *Fusarium* spp. are natural endophyte in banana and the fungi are not restricted to a cultivar or genomes as a particular host.

Different degrees of activities toward *R. similis* were found among the 28 *Fusarium* spp. isolates used in screening studies on the cultivar Gran Enano. 11 isolates caused a reduction in the number of *R. similis*/g root higher than 70%. In contrast, only nine of 28 isolates were considered less active due to the their reduction activity was lower than 30%. These differences in activity among the isolates may be explained by the ability of the fungi to grow extensively inside and then impede the penetration of nematodes in the roots (Pocasangre *et al.*, unpublished). Hallmann and Sikora (1996) found that non-pathogenic *Fusarium oxysporum* strains were the most effective endophytic fungi toward plant parasitic nematodes. They also found that the toxic metabolites produced by *Fusarium oxysporum* were highly effective towards sedentary parasites and less effective towards migratory endoparasites.

The results of our investigations suggest that the endophytic fungi could be used to improve the critical hardening phase of banana micropropagation and reduce initial applications of pesticides at this stage. The duration of biological control as the plant matures still needs further study.

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The authors work at the Institute of Plant Pathology, Soil-Ecosystem Phytopathology Section, University of Bonn, Nussallee 9, D-53115 Bonn, Germany.

Screening of Fusarium wilt resistant bananas to root-lesion nematodes

R. Stoffelen, R. Verlinden, J. Pinochet, R. Swennen and D. De Waele

Many important banana genotypes and most of the world's banana production areas are affected by *Fusarium* wilt or Panama disease caused by the soilborne fungus *Fusarium oxysporum* f. sp. *cubense* (*Foc*). The fungus colonizes and occludes the xylem of the host plant and causes thereby reddish-brown discoloration. Leaves become bright yellow, wilt and collapse around the pseudostem (Ploetz 1994). The pathogen can survive for long periods in the soil and cannot be controlled with fungicides. As a consequence, susceptible genotypes cannot be grown in an infested field for up to 30 years.

In the framework of the International *Musa* Testing Programme (IMTP) phase II of INIBAP, the resistance of improved banana and plantain hybrids to *Fusarium* wilt was evaluated (Orjeda 1998). As a result of this programme, several sources of resistance to these fungal diseases are now available (Shepherd *et al.* 1994, Pires de Matos *et al.* 1998, Orjeda *et al.* 1999, Tang and Hwang 1999).

Banana and plantain are not only attacked by fungi but also by other pathogens including plant-parasitic nematodes of which *Radopholus similis*, *Pratylenchus coffeae*, *Pratylenchus goodeyi*, *Helicotylenchus multicinctus* and *Meloidogyne* spp. are the most common and damaging species (Gowen and Quénéhervé 1990). In nematode-infested fields, losses caused by reduced plant growth, longer vegetative period, smaller bunches, toppling and reduced longevity of the plantation can be very high.

The objective of this study was to evaluate ten *Fusarium* wilt resistant or moderately resistant *Musa* genotypes, as identified by IMTP, on their resistance to the root-lesion nematodes *R. similis* and *P. coffeae*. Three susceptible reference genotypes 'Gros Michel', 'Williams' and 'Bluggoe' were included as well (Jones 1994). The resistance to *P. goodeyi* and *Meloidogyne* spp. of these genotypes was recently evaluated by Pinochet *et al.* (1998). Throughout the study, the methodology as described by Speijer and De Waele (1997) was followed.

Materials and methods

Preparation of plants

In vitro propagated plantlets were transplanted in 1-liter plastic pots filled with autoclaved loamy sand. The pots were maintained in a greenhouse at an ambient temperature of 20-27°C and a 12-hour photoperiod. The pots were irrigated as needed and fertilized with a hydroponic solution every three weeks after nematode inoculation.

Preparation of nematode inoculum

The *R. similis* and *P. coffeae* populations used were originally isolated from infected *Musa* roots: *R. similis* from a banana cultivar 'Valery' (AAA-group) in Talamanca, Costa Rica, and *P. coffeae* from a plantain (AAB-group) in Kade, Ghana. *Radopholus similis* and *P. coffeae* were reared monoxenically on carrot disk cultures at 28°C in the dark (Moody *et al.* 1973, Pinochet *et al.* 1995). The inoculum was adjusted to deliver a suspension of nearly 1000 eggs and vermiform living nematodes per plant in 3 holes made in the soil around the roots.

Estimation of host plant resistance

The plants were inoculated with nematodes four weeks after acclimatization. Plants inoculated with *R. similis* were harvested at eight weeks after inoculation and those with *P. coffeae* two weeks later because of the longer life cycle of this nematode. A subsample of 15 g of fresh roots was macerated in a blender during two periods of 10Ó separated by a 5Ó interval. The nematodes were then passed through 250, 106 and 40 mm-pore sieves. The nematodes remaining on the 40 µm-pore sieve were collected and counted in 6-ml aliquots of each sample using a binocular microscope.

Experimental design and data analysis

The genotypes were divided into two batches, each including 'Grande Naine' (AAA-group) as susceptible reference cultivar. Four successive experiments were conducted to determine the host plant response of the genotypes of both batches to *R. similis* and *P. coffeae*. Each experiment was a randomized complete block with eight replicates per genotype. Nematode numbers were $log_{10}(x + 1)$ transformed and subjected to analysis of variance (ANOVA). The means were separated by Tukey's test at $P \leq 0.05$.

Results

Radopholus similis

In batch 1, significant differences in susceptibility to *R. similis* were observed (Table 1). The nematode numbers per root system of the two 'Pisang Jari Buaya' accessions and 'Yangambi Km5' were significantly lower compared to the susceptible reference cultivar 'Grande Naine'. Because the numbers of nematodes recovered per root system were lower than the inoculum, the 'Pisang Jari Buaya' accessions ITC0312 and ITC0690 and 'Yangambi Km5' can be considered resistant to *R. similis*. The susceptibility to *R. similis* of the genotypes 'Gros Michel', 'FHIA-01' and 'Bluggoe' was not significantly different from 'Grande Naine'.

All genotypes screened in batch 2 were statistically as susceptible to R. *similis* as 'Grande Naine': 'PA 03.22', 'PV 03.44', 'P. lilin', 'Saba', 'GCTCV 215', 'GCTCV 119' and 'Williams' (Table 1). Only the nematode numbers recovered from 'PA 03.22' were significantly lower compared to 'Williams'.

Pratylenchus coffeae

All genotypes screened in batches 1 and 2 were statistically as susceptible to *P. coffeae* as 'Grande Naine', the susceptible reference cultivar (Table 1). In batch 1, the highest number of nematodes per root system was recovered from 'Bluggoe'. 'Bluggoe' was significantly more susceptible to *P. coffeae* compared to all other genotypes evaluated in batch 1 except 'Grande Naine'. In batch 2, the highest number of nematodes per root system was recovered from 'Saba'. 'Saba' was significantly more susceptible to *P. coffeae* compared to all other genotypes evaluated in batch 2, including 'Grande Naine' (Table 1).

Discussion

Out of the 14 *Musa* genotypes three show resistance to *R. similis*: the 'Pisang Jari Buaya' accessions ITC0312 and ITC0690, and 'Yangambi Km5'. The resistance of 'Pisang Jari Buaya' and 'Yangambi Km5' to *R. similis* has been reported previously (Wehunt *et al.* 1978, Pinochet and Rowe 1979, Price 1994, Fogain and Gowen 1998). The 'Pisang Jari Buaya' accessions belong to the Pisang Jari Buaya subgroup which consists of diploid AA varieties of which several varieties showed either

Table 1. Nematode reproduction on ten Fusarium resistant and three Fusarium susceptible genotypes and the reference cultivar 'Grande Naine' measured eight (*R. similis*) or ten (*P. coffeae*) weeks after inoculation.

Accession name	Reaction to *Fusarium*	ITC code	Numbers of *R. similis* per root system		Numbers of *P. coffeae* per root system	
Batch 1			**P_i= 1006 eggs and vermiforms**		**P_i= 1004 eggs and vermiforms**	
Pisang Jari Buaya	resistant	0312	673	*a*	1673	*a*
Yangambi Km5	resistant	1123	792	*a*	1724	*a*
Pisang Jari Buaya	resistant	0690	999	*a*	1374	*a*
Gros Michel	susceptible	1122	2513	*ab*	1392	*a*
FHIA-01	resistant	0504	3790	*bc*	1585	*a*
Bluggoe	susceptible	0643	9786	*c*	4590	*B*
Grande Naine		*1256*	*6761*	*bc*	*2082*	*ab*
Batch 2			**P_i= 926 eggs and vermiforms**		**P_i= 1178 eggs and vermiforms**	
PA 03.22	resistant	1261	4987	*A*	9530	*B*
PV 03.44	resistant	1262	8400	*AB*	6298	*AB*
Pisang lilin	resistant	0001	10 857	*AB*	8731	*AB*
Saba	resistant	1138	12 754	*AB*	27 817	*C*
GCTCV 215	resistant	1271	13 156	*AB*	4454	*A*
GCTCV 119	resistant	1282	14 686	*AB*	8278	*AB*
Williams	susceptible	0570	23 216	*B*	12 936	*B*
Grande Naine		*1256*	*14 686*	*AB*	*9601*	*AB*

ITC = INIBAP Transit Center; P_i = initial population.

Data were $log_{10}(x + 1)$ transformed before analysis. Means in the same column followed by the same letter do not differ significantly according to Tukey's method ($P \leq 0.05$).

resistance to or are less susceptible to *R. similis* (Wehunt *et al*. 1978). Our observations that two accessions of 'Pisang Jari Buaya' originating from different localities (accession ITC0312 from Malaysia; accession ITC0690 from Indonesia) are resistant to *R. similis* reconfirm the status of this genotype as *R. similis* resistant. The use of 'Pisang Jari Buaya' in the *Musa* breeding programme of the *Fundación Hondureña de Investigación Agrícola* (FHIA) in Honduras, resulted in the release of the commercial hybrid 'FHIA-01' (AAAB) (Rowe and Rosales 1993). Recent studies showed that 'FHIA-01' was partially resistant to *R. similis* when 3- to 4-months-old plants grown from corms were evaluated. However, plants grown from *in vitro* maintained tissue culture plants were as susceptible to *R. similis* as the susceptible reference cultivars (INIBAP 1998). Our results confirm that 'FHIA-01' plants derived from *in vitro* propagation are not resistant to *R. similis* at least during eight weeks after inoculation.

'Yangambi Km5', the second source of resistance to R. *similis*, is a triploid AAA variety collected in the Democratic Republic of Congo. Although male and female fertile, this variety is not being used in *Musa* breeding programmes because all progenies produce abnormal leaves and/or erect and semi-erect bunches.

'Gros Michel' is reported as a cultivar with lower susceptibility to *R. similis* compared with the susceptible cultivar 'Poyo' (AAA-group) (Mateille 1992, Price 1994). In this study the host plant response of 'Gros Michel' is not clear because the number of nematodes per root system is not significantly different from the susceptible reference cultivar 'Grande Naine' and from the resistant 'Pisang Jari Buaya' accessions and 'Yangambi Km5'.

None of the 14 *Musa* genotypes evaluated in this study is resistant to *P. coffeae*. These results confirm earlier reports on the susceptibility of 'Pisang Jari Buaya' to *P. coffeae* (Pinochet and Rowe 1978, INIBAP 1998). Partial resistance of 'Yangambi Km 5' to *P. coffeae* is observed on *in vitro* plants and corms after inoculation (INIBAP 1998). However in this study, 'Yangambi Km5' was as susceptible to *P. coffeae* as the reference cultivar 'Grande Naine'.

All *Musa* sources of resistance to *F. oxysporum* f. sp. *cubense* with exception of 'Pisang Jari Buaya' and 'Yangambi Km5', are highly susceptible to both *R. similis* and *P. coffeae*. Screening by Pinochet *et al.* (1998) revealed that all genotypes were also susceptible to *Meloidogyne javanica* and *M. incognita* and were good hosts for *P. goodeyi* except 'Yangambi Km 5'. When these genotypes are grown in fields infested with these nematodes yield losses may be expected.

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Ruth Stoffelen, Raf Verlinden, Rony Swennen and **Dirk De Waele** work at the Laboratory of Tropical Crop Improvement, Catholic University of Leuven (K.U.Leuven), K. Mercierlaan 92, 3001 Heverlee, Belgium. **Jorge Pinochet** works at Agromillora Catalana S. A., El Rebato, s/n, 08739 T. M. Subirats, Spain.

Screening of Vietnamese *Musa* germplasm for resistance and tolerance to root-knot and root-lesion nematodes in the greenhouse

I. Van den Bergh, D. De Waele, Ho Huu Nhi, Duong Thi Minh Nguyet, Nguyen Thi Tuyet and Doan Thi Thanh

Vietnam lies in the origin centre of bananas, with excellent conditions for banana production. Among the fruit crops, bananas rank first in terms of gross output and production area (Vinh and Quy 1995). Bananas are mostly grown for domestic consumption.

During 1994-1995, a banana collection mission was held in Vietnam. More than 80 genotypes and wild species were collected (Khoi and Valmayor, 1995). Following preliminary characterisation, 64 distinct genotypes and 9 wild species have been identified (INIBAP 1997). These genotypes are being maintained in a field collection at the Phu Ho Fruit Research Institute (Vinh Phu province) and in an *in vitro* collection at the Vietnam Agricultural Science Institute (Hanoi). A part has also been sent to the INIBAP Transit Centre (ITC) in Leuven (Belgium) to be included in the world collection of bananas.

These genotypes must now be evaluated for their overall performance and their disease and pest resistance/tolerance characteristics. In this study, the most important genotypes were screened for their resistance/tolerance to *Meloidogyne* spp., root-knot nematodes that cause galling of the primary and secondary roots (De Waele and Davide 1999), and *P. coffeae*, root-lesion nematodes that cause a necrotic and reduced root system (Stoffelen *et al*. 1999).

Materials and methods

Two experiments with *Meloidogyne* spp. and two with *P. coffeae* were carried out. The genotypes used in the experiments are listed in Table 1. In total, 19 Vietnamese banana genotypes and two genotypes received from ITC were screened. The genotypes 'Yangambi Km 5', 'Gros Michel' and 'Grand Nain' were included as reference genotypes: highly resistant to R. *similis*, moderately resistant to R. *similis* and susceptible to all nematodes, respectively (Speijer and De Waele 1997).

For all the experiments, *in vitro* plantlets were used. The plantlets were cultured and propagated on Murashige and Skoog (1962) medium. They were transferred to trays, filled with sterilised sand and treated several times with the fungicide Daconil. After two to three weeks, the plants were transferred to 12-cm-diameter plastic pots, filled with a mixture of sterilised soil and humus. They were again treated with Daconil and also with the insecticides Suprathion, Ortus, Trebon or Dipterex. The plants were watered as needed and a nutritional solution was applied two times.

After 6 to 14 weeks, 20 plants of every genotype were chosen at random and arranged in a randomised complete block design. Of every genotype, 10 plants were infested with 4000 juveniles and eggs of *Meloidogyne* spp., obtained from mixed tomato roots, or 1000 vermiform nematodes of *P. coffeae*, obtained from mixed carrot discs (O' Bannon and Taylor 1968). The 10 other plants were used as control plants.

The plants were harvested 11 to 15 weeks after inoculation. Several data were recorded to assess the damage caused by the nematodes (a measure for the tolerance/sensitivity of the genotypes) and the reproduction of the nematodes (a measure for the resistance/susceptibility of the genotypes).

Following the method described by Speijer and de Waele (1997), the following data were recorded:

General data: plant height (cm), shoot weight (g), weight of the root system (g), number of standing leaves, girth at the base (cm).

Data on nematode reproduction: number of egg-laying females on the section of five 10-cm, pieces of roots (ELF), for experiment with *Meloidogyne* spp., nematodes per 10 g of roots and per root system.

Data on root damage assessment: percentage of dead roots (%), root-knot galling (RKG), for experiment with *Meloidogyne* spp., root necrosis index (RNI, %), for experiment with *P. coffeae.*

The maceration-sieving method was used for the extraction of the nematodes.

For the statistical analysis of the results, the software package SPSS 9.0 for Windows was used. For normal populations, ANOVA was used to analyze the data and mean separation was performed with Tukey's Honestly Significant Difference Test. For non-normal populations, the non-parametric Kruskal-Wallis Rank Test was used to analyse the data and mean separation

Table 1. Genotypes used in the screening experiments.

Name	Group	VN- number	ITC code	*Meloidogyne* spp.		*P. coffeae*	
				1998	1999	1998	1999
'Tay But'	AA	VN1-001	ITC1367	✔		✔	✔
'Ngu Tien'	AA	VN1-004	ITC1420	✔		✔	
'Com Lua'	AA	VN1-117	ITC1421		✔		✔
'Ngu Thoc'	AA	VN1-017	ITC1358		✔		✔
'Tien'	AA	VN1-075	ITC1368			✔	
'Tieu Mien Nam'	AA	VN1-120	ITC1370	✔			✔
'Tieu Xanh'	AAA	VN1-006	ITC1406	✔		✔	
'Tieu Cao'	AAA	VN1-042	ITC1376	✔		✔	
'Tieu Vua Trang'	AAA	VN1-064			✔		✔
'Ben Tre'	AAA	VN1-065	ITC1410		✔		
'Cao Hong'	AAA	VN1-079	ITC1407	✔		✔	✔
'Man'	AAB	VN1-035	ITC1379		✔		✔
'Com Chua'	AAB	VN1-116	ITC1380		✔		✔
'Xiem Mat'	AAB	VN1-141	ITC1425	✔		✔	
'Voi'	AAB	VN1-144	ITC1381	✔		✔	
'Tay'	ABB	VN1-012	ITC1426		✔		
'Gao'	ABB	VN1-015	ITC1357	✔		✔	
'Ngop Lun'	ABB	VN1-024		✔		✔	
'Ngop Cao'	ABB	VN1-025	ITC1364		✔		✔
'FHIA-23'	AAAA		ITC1265	✔		✔	
'Kluai Hom Khom'	AAA		ITC0527	✔		✔	
'Yangambi Km 5'	AAA		ITC1123	✔		✔	✔
'Gros Michel'	AAA		ITC1122		✔		✔
'Grand Nain'	AAA		ITC1256		✔		✔

was performed with the KW-Bonferroni Method. The combined confidence level of all the paired tests is at least 0.95 (combined confidence coefficient $\alpha = 0.05$).

Results and discussion

Meloidogyne spp.

General data

In the first experiment, infection with *Meloidogyne* spp. resulted in an increase in the weight of the root system and a decrease in the number of standing leaves. There was no effect on the plant height, the shoot weight or the girth of the plants. In the second experiment, infection with *Meloidogyne* spp. had no effect on any of the measured general data (Table 2).

Nematode reproduction

In the first experiment, there were no differences in the numbers of nematodes of the different genotypes. In the second experiment, there were no differences in the numbers of egg-laying females or the numbers of nematodes per 10 g of roots of the different genotypes, but there were some significant differences in the numbers of nematodes per root system of the different genotypes. 'Ngu Thoc' had a significantly lower number of nematodes per root system than 'Tieu Vua Trang', 'Com Chua' and 'Ben Tre' (Table 3).

Root damage assessment

There were never differences in the percentages of dead roots of the different genotypes, but in both experiments, some significant differences in the root-knot galling of the different genotypes could be detected. In the first experiment, 'Yangambi Km 5' showed a significantly lower root-knot galling than 'Voi'. In the second experiment, 'Man', 'Ngu Thoc' and 'Tay' showed a significantly lower root-knot galling than 'Ben Tre' (Table 3).

Discussion

in the first experiment, the knots formed by *Meloidogyne* spp. can probably explain the increase in the weight of the root system of the infected plants. In the second experiment, the average root-knot galling was much lower than in the first experiment (0.8 in comparison to 2.4), which might explain why in the second experiment, infection with *Meloidogyne* spp. had no effect on the root weight. The number of egg-laying females and nematodes per 10 g of roots and per root system was also lower in the second experiment than in the first (Table 3). This might explain why in the second experiment, infection with *Meloidogyne* spp. had no effect on the number of standing leaves.

In the first experiment, all the genotypes showed the same level of resistance/susceptibility to *Meloidogyne* spp. The second experiment indicates that 'Ngu Thoc' might show some resistance to *Meloidogyne* spp., while 'Tieu Vua Trang', 'Com Chua' and 'Ben Tre' are probably very susceptible to *Meloidogyne* spp. These results are however not very convincing and further research is needed.

In both experiments, there were some significant differences in the root-knot galling of the different genotypes, which indicates the existence of differences in tolerance/sensitivity of the genotypes to *Meloidogyne* spp. 'Yangambi Km 5', 'Man', 'Ngu Thoc' and 'Tay' possibly show some tolerance to the gall-forming activity of *Meloidogyne* spp. For 'Ngu Thoc', the low root-knot galling could also be a consequence of the low number of nematodes in the roots instead of an evidence of tolerance. 'Voi' and 'Ben Tre' are probably highly sensitive to the gall-forming activity of *Meloidogyne* spp.

P. coffeae

General data

In the first experiment, infection with P. *coffeae* resulted in a decrease in the height of the plants and the shoot weight. There was no effect on the weight of the root system, the number of standing leaves or the girth of the plants. In the second experiment, infection with P. *coffeae* had no effect

Table 2. *Meloidogyne* spp.: results of the general data of the experiments.

	Plant height (cm)	Shoot weight (g)	Root weight (g)	Standing leaves	Girth (cm)
Experiment 1998	A	B	C	D	E
Not infected with *Meloidogyne* spp.	27.6 *a*	81.8 *a*	28.3 *a*	6.7 *b*	8.2 *a*
Infected with *Meloidogyne* spp.	27.8 *a*	79.0 *a*	31.6 *b*	6.2 *a*	8.3 *a*
Experiment 1999	F	G	H	I	J
Not infected with *Meloidogyne* spp.	28.2 *a*	117.2 *a*	52.6 *a*	5.7 *a*	10.5 *a*
Infected with *Meloidogyne* spp.	27.5 *a*	112.8 *a*	54.7 *a*	5.7 *a*	10.4 *a*

A, D, E, I, J: Data were not transformed before analysis.

B, F, H: Data were $\log_{10}x$ transformed before analysis. The untransformed data are presented in the table.

C, G: Data were square root transformed before analysis. The untransformed data are presented in the table.

Means in the same column followed by the same letter do not differ significantly according to Tukey (A, B, C, F, G, H) or KW-Bonferroni (D, E, I, J) for $\alpha = 0.05$.

Table 3. *Meloidogyne* spp.*:* results of the damage assessment and nematode reproduction data.

Name	Group	Percentage of dead roots (%)	RKG(1)	ELF(2)	Nematodes per 10 g of roots	Nematodes per root system
Experiment 1998		A	B	C	D	E
'Tay But'	AA	2.2 *a*	2.0 *ab*	4.3 *a*	7057 *a*	17036 *a*
'Ngu Tien'	AA	0.9 *a*	1.7 *ab*	3.6 *a*	7039 *a*	21385 *a*
'Tieu Mien Nam'	AA	1.5 *a*	2.2 *ab*	3.9 *a*	7813 *a*	21626 *a*
'Tieu Xanh'	AAA	5.4 *a*	2.4 *ab*	4.0 *a*	8579 *a*	17448 *a*
'Tieu Cao'	AAA	2.0 *a*	2.8 *ab*	3.6 *a*	5896 *a*	21918 *a*
'Cao Hong'	AAA	7.4 *a*	2.6 *ab*	3.6 *a*	6552 *a*	23213 *a*
'Xiem Mat'	AAB	2.2 *a*	2.7 *ab*	3.5 *a*	8003 *a*	30107 *a*
'Voi'	AAB	3.1 *a*	2.9 *b*	4.5 *a*	8699 *a*	26333 *a*
'Gao'	ABB	2.0 *a*	2.8 *ab*	4.0 *a*	3676 *a*	14185 *a*
'Ngop Lun'	ABB	2.0 *a*	2.6 *ab*	3.9 *a*	4939 *a*	15870 *a*
'FHIA-23'	AAAA	4.3 *a*	2.6 *ab*	3.9 *a*	5252 *a*	17688 *a*
'Kluai Hom Khom'	AAA	2.2 *a*	2.3 *ab*	4.0 *a*	4213 *a*	11835 *a*
'Yangambi Km 5'	AAA	2.5 *a*	1.4 *a*	3.6 *a*	6707 *a*	21371 *a*
Total		**2.9**	**2.4**	**3.9**	**6493**	**19990**
Experiment 1999		F	G	H	I	J *I* *D*
'Com Lua'	AA	4.5 *a*	0.8 *ab*	1.0 *a*	3320 *a*	14096 *a* *ab*
'Ngu Thoc'	AA	1.8 *a*	0.4 *a*	0.5 *a*	1431 *a*	6317 *a* *a*
'Tieu Vua Trang'	AAA	0.0 *a*	1.5 *ab*	1.3 *a*	4368 *a*	28154 *a* *b*
'Ben Tre'	AAA	0.0 *a*	1.9 *b*	1.7 *a*	4056 *a*	18630 *a* *b*
'Man'	AAB	0.0 *a*	0.2 *a*	0.2 *a*	2347 *a*	12020 *a* *ab*
'Com Chua'	AAB	0.0 *a*	0.6 *ab*	0.5 *a*	3052 *a*	27297 *a* *b*
'Tay'	ABB	0.0 *a*	0.4 *a*	0.2 *a*	1308 *a*	7252 *a* *ab*
'Ngop Cao'	ABB	0.0 *a*	1.0 *ab*	0.5 *a*	2508 *a*	14403 *a* *ab*
'Gros Michel'	AAA	0.0 *a*	0.7 *ab*	0.8 *a*	1468 *a*	7163 *a* *ab*
'Grand Nain'	AAA	0.0 *a*	0.5 *ab*	1.0 *a*	2360 *a*	9260 *a* *ab*
Total		**0.7**	**0.8**	**0.8**	**2661**	**15039**

A, B, C, F, G, H: Data were not transformed before analysis.

D, E, I, J: Data were $\log_{10}$ (x + 1) transformed before analysis. The untransformed data are presented in the table.

Means in the same column followed by the same letter do not differ significantly according to Tukey (D, E, I, J), Duncan (J) or KW-Bonferroni (A, B, C, F, G, H) for (= 0.05.

(1) = no galling; 1 = trace infections with a few small galls; 2 = < 25 % roots galled; 3 = 25 - 50% roots galled; 4 = 50 - 75% roots galled; 5 = > 75 % roots galled.

(2) = no egg masses; 1 = 1 - 2 egg masses; 2 = 3 - 10 egg masses; 3 = 11 - 30 egg masses; 4 = 31 - 100 egg masses; 5 = > 100 egg masses.

on any of the measured general data (Table 4).

Nematode reproduction

In the first experiment, 'Yangambi Km 5' and 'Tieu Xanh' had a lower number of nematodes than 'Ngop Lun' and 'Voi'. In the second experiment, 'Ngop Cao' was the only genotype with a high number of nematodes (Table 5).

Root damage assessment

There were never differences in the percentages of dead roots of the different genotypes. Only in the first experiment, some significant differences in the root necrosis of the different genotypes could be detected. 'Yangambi Km 5' showed a significantly lower root necrosis than 'Ngop Lun' (Table 5).

Discussion

In the second experiment, the numbers of nematodes found in the roots of almost all plants were very low, which might explain why no differences between the infected and non-infected plants could be found.

'Ngop Lun', 'Voi' and 'Ngop Cao' are very susceptible to *P. coffeae*. In the first experiment, 'Yangambi Km 5' and 'Tieu Xanh' had the lowest number of nematodes in the roots; but one can not directly jump to the conclusion that these genotypes are resistant to *P. coffeae*, since in the second experiment, the number of nematodes found in the roots of 'Yangambi Km 5' did not significantly differ from the number found in the roots of the highly susceptible reference genotype 'Grand Nain'. In both experiments, this number was low for almost all plants.

In the first experiment, high numbers of nematodes in the roots coincided with high damage levels and vice versa. The low levels of damage in the second experiment can not be attributed to tolerance of the genotypes, but are probably due to the low numbers of nematodes found in the roots of almost all plants. Only for 'Ngop Cao', one can conclude that a significantly higher number of nematodes in the roots did not cause any significant damage.

Conclusion

***Meloidogyne* spp.**

Infection with *Meloidogyne* spp. can result in an increase in the weight of the root system and a decrease in the number of standing leaves, but further research is needed. There was never an effect of infection with *Meloidogyne* spp. on the plant height, the shoot weight or the girth of the plants.

There is some indication that 'Ngu Thoc' might show some resistance to *Meloidogyne* spp., while 'Tieu Vua Trang', 'Com Chua' and 'Ben Tre' are very susceptible to *Meloidogyne* spp.

'Yangambi Km 5', 'Man', 'Ngu Thoc' and 'Tay' possibly show some tolerance to the gall-forming activity of *Meloidogyne* spp, while 'Voi' and 'Ben Tre' are highly sensitive to the gall-forming activity of *Meloidogyne* spp.

P. coffeae

Infection with *P. coffeae* can result in a decrease in the height of the plants and the shoot weight, but further research is needed. There was never an effect of infection with *P. coffeae* on the weight of the root system, the number of standing leaves or the girth of the plants.

'Ngop Lun', 'Voi' and 'Ngop Cao' are very susceptible to *P. coffeae*. There is some indication that 'Yangambi Km 5' and 'Tieu Xanh' might show some resistance to *P. coffeae*.

'Ngop Cao' and 'Yangambi Km 5' were the only possible sources of tolerance found in the experiments.

Further research and screening experiments are certainly needed. Since the numbers of nematodes found in the root system were in general very low, even on the highly susceptible reference genotype 'Grand Nain', research on pathogenicity (reproductive and damage potential) of the *P. coffeae* population used in the experiments might reveal some interesting information.

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D. De Waele works at the Laboratory of Tropical Crop Improvement, Catholic University of Leuven (K.U.Leuven), K. Mercierlaan 92, 3001 Heverlee, Belgium. The **other authors** work at the Vietnam Agricultural Science Institute, Van Dien, Thanh Tri, Hanoi, Vietnam.

Table 4. *P. coffeae*: general data of the experiments.

	Plant height (cm)	Shoot weight (g)	Root weight (g)	Standing leaves	Girth (cm)
Experiment 1998	A	B	C	D	E
Not infected with P. *coffeae*	22.4 *b*	52.7 *b*	16.6 *a*	6.5 *a*	6.7 *a*
Infected with P. *coffeae*	21.3 *a*	47.2 *a*	15.4 *a*	6.4 *a*	6.5 *a*
Experiment 1999	F	G	H	I	J
Not infected with P. *coffeae*	30.9 *a*	124.7 *a*	57.0 *a*	5.5 *a*	8.2 *a*
Infected with P. *coffeae*	30.6 *a*	119.4 *a*	53.2 *a*	5.4 *a*	8.1 *a*

A, B, G, H: Data were square root transformed before analysis. The untransformed data are presented in the table.

C: Data were cube root transformed before analysis. The untransformed data are presented in the table.

F: Data were $\log_{10}x$ transformed before analysis. The untransformed data are presented in the table.

D, E, I, J: Data were not transformed before analysis.

Means in the same column followed by the same letter do not differ significantly according to Tukey (A, B, C, F, G, H) or KW-Bonferroni (D, E, I, J) for α= 0.05.

Table 5. *P. coffeae*: results of the damage assessment and nematode reproduction data.

Name	Group	Dead roots (%)	RNI (%)	Nematodes per 10 g of roots	Nematodes per root system
Experiment 1998		A	B	C	D
'Tay But'	AA	1.7 *a*	1.9 *ab*	94 *ab*	114 *abc*
'Ngu Tien'	AA	0.9 *a*	0.6 *ab*	146 *ab*	208 *abc*
'Tien'	AA	1.8 *a*	1.9 *ab*	93 *ab*	174 *abc*
'Tieu Xanh'	AAA	4.5 *a*	0.3 *ab*	65 *a*	69 *ab*
'Tieu Cao'	AAA	0.0 *a*	0.9 *ab*	129 *ab*	221 *abc*
'Cao Hong'	AAA	0.0 *a*	0.3 *ab*	124 *ab*	313 *abc*
'Xiem Mat'	AAB	1.4 *a*	0.9 *ab*	344 *ab*	648 *abc*
'Voi'	AAB	7.1 *a*	12.8 *ab*	2,297 *b*	2,894 *bc*
'Gao'	ABB	1.7 *a*	2.2 *ab*	2,031 *ab*	3,890 *abc*
'Ngop Lun'	ABB	1.0 *a*	8.7 *b*	2,840 *b*	5,027 *c*
'FHIA-23'	AAAA	0.7 *a*	1.7 *ab*	393 *ab*	658 *abc*
'Kluai Hom Khom'	AAA	0.0 *a*	1.2 *ab*	601 *ab*	577 *abc*
'Yangambi Km 5'	AAA	0.0 *a*	0.1 *a*	29 *a*	42 *a*
Total		**1.4**	**2.3**	**662**	**1,093**
Experiment 1999		E	F	G	H
'Tay But'	AA	0.0 *a*	0.0 *a*	60 *ab*	247 *ab*
'Com Lua'	AA	0.0 *a*	0.2 *a*	28 *a*	115 *a*
'Ngu Thoc'	AA	1.8 *a*	0.5 *a*	28 *a*	153 *a*
'Tieu Mien Nam'	AA	0.0 *a*	0.2 *a*	16 *a*	75 *a*
'Tieu Vua Trang'	AAA	2.9 *a*	0.7 *a*	48 *ab*	228 *ab*
'Cao Hong'	AAA	0.0 *a*	0.8 *a*	72 *ab*	425 *ab*
'Man'	AAB	0.0 *a*	0.0 *a*	16 *a*	121 *a*
'Com Chua'	AAB	0.0 *a*	0.3 *a*	16 *a*	109 *a*
'Ngop Cao'	ABB	0.0 *a*	0.7 *a*	534 *b*	2,886 *b*
'Yangambi Km 5'	AAA	3.8 *a*	0.0 *a*	12 *a*	46 *a*
'Gros Michel'	AAA	0.0 *a*	0.0 *a*	20 *a*	105 *a*
'Grand Nain'	AAA	0.0 *a*	1.6 *a*	36 *a*	118 *a*
Total		**0.7**	**0.4**	**75**	**390**

Means in the same column followed by the same letter do not differ significantly according to KW-Bonferroni for α= 0.05.

Somatic embryogenesis in liquid media. Maturation and enhancement of germination of the hybrid cultivar FHIA-18 (AAAB)

R. Gomez Kosky, T. Gilliard, L. A. Barranco and M. Reyes

Annual production of bananas and plantains is estimated to be approximately 88 million tonnes (FAO 1999), making them one of the largest food crops in the world after rice, maize and wheat (INIBAP 1997).

The crop is under serious threat from phytosanitary problems such as black Sigatoka (*Mycosphaerella fijiensis* Morelet), Panama disease or banana wilt (*Fusarium oxysporum* f. sp. *cubense*), the virus diseases banana bunchy top (BBTV-Banana Bunchy Top Virus) and streak mosaic (BSV-Banana Streak Virus) and nematodes, which cause enormous yield losses. All this increases production costs and the development of new varieties is increasingly urgent.

Since 1984, FHIA (*Fundación Hondureña de Investigación Agrícola*) has run a vast programme of research on hybrids resistant to black Sigatoka. Among these, the cultivar FHIA-18 (AAAB) displays tolerance to the disease, good field behaviour and very good agronomic qualities. It is now one of the main cultivars grown in Cuba.

The purpose of the work described here was the development, within the framework of somatic embryogenesis of banana, of a liquid culture medium for the maturation of somatic embryos, for increasing current germination percentages and for detecting the appearance of possible somaclonal variations during plant weaning.

Material and methods

Preparation of cell suspensions

The plant material used consisted of immature male flowers from inflorescences of the hybrid cultivar FHIA-18 (AAAB). The latter were collected directly from the plants at a distance of approximately 20-30 cm from the last female flower. The male buds were then cut 10 cm from the tip and the bracts were removed to give 3-cm lengths ready for transfer to the laboratory.

The material was disinfected with alcohol 70% (v/v) for 15 min. Fourteen hands or rows of flowers were then extracted under a binocular microscope from among those closest to the flower meristem. The 5th to the 12th were placed in flasks containing the MA_1 induction medium proposed by Escalant *et al*. (1994) for callus formation.

The cell suspensions were initiated from highly embryogenic cultures of somatic embryos derived from callus formed in five months from the hands. Medium MA_2 proposed by Bieberach (1995) was used for this.

Mass of approximately 150-200 mg fresh weight somatic embryos were placed in 25-ml Erlenmeyer flasks containing 2 to 3 ml medium. The flasks were then placed on an orbital agitator at 90 rpm at 27°C in continuous darkness.

The cell suspension formed was filtered on 500µm metal filters after 15 days. The different studies performed during this work were performed on these cell suspension filtrates.

Subculturing was performed every 15 days in conformity with the protocol developed by Escalant *et al*. (1994). Cell growth was evaluated by the sedimented cell volume method proposed by Schoof (1997). For this, 15-ml aliquots of cell suspension were placed in 15-ml graduated conical tubes. The volume of sedimented cells was measured after sedimentation for 5 min. At each subculture, the final cell concentration was adjusted to 3% independently of total capacity of the Erlenmeyer flask used.

Formation of somatic embryos

Somatic embryos were obtained on modified Schenck and Hildebrandt's medium (1962): SH mineral salts; Murashige and Skoog vitamins (1962), malt extract 100 mg/l, L-glutamine 100 mg/l, L-proline 230 mg/l, naphthaleneacetic acid (ANA) 0.2 mg/l, kinetin 0,05 mg/l, lactose 10 g/l, zeatin 0.05 mg/l, sucrose 45 g/l, pH 5.3.

The influence of the initial concentration on the formation of somatic embryos was studied by testing four cell cluster fresh weights (50, 100, 250 and 500 mg) for 25 ml medium. The number of embryos formed was evaluated after 15 and 30 days of culture by taking several 1-ml cell suspension samples after agitation of the flasks for several seconds. Several repetitions per test were performed in 250-ml Erlenmeyer flasks under culture conditions identical to those described in the preceding paragraph.

Secondary multiplication of somatic embryos

The purpose of the experiment was to determine the effect of initial inoculation density on the secondary multiplication of somatic embryos in agitated liquid medium. A basic MS medium was used, complemented with 0.3 mg 6-benzylaminopurine (6-BAP), 1 mg indolacetic acid (AIA), 3% sucrose, with pH 5.3 before autoclaving. Inoculation densities of 0.2, 0.4 and 0.6 g fresh weight somatic embryos at the globular stage were tested in 25 ml medium with five repetitions in 250-ml Erlenmeyer flasks. The different tests were weighed on an analytical balance on day 60 of culture. The number of embryos formed was evaluated by placing several 1 g fresh weight samples of somatic embryos in Petri dishes 5 cm in diameter containing a water-Phytagel mixture. Counting was performed under a binocular microscope after solidification of the mixture. The embryos were also measured with a graduated rule on the reverse side of the dish.

Maturation of somatic embryos

Three different concentrations were tested for the maturation of the somatic embryos obtained: 400, 800 and 1,000 mg fresh weight of somatic embryos at globular stage for 30 ml modified Murashige and Skoog medium (1962): MS salts, MS vitamins, biotin 1.0 mg/l, 6-BAP 0.5 mg/l, AIA 2.0 mg/l, sucrose 45 mg/l, pH 5.8 in 250 ml Erlenmeyer flasks agitated at 90 rpm, 27°C in continuous darkness.

Maturation was evaluated weekly. Samples were taken for this and observed under a binocular microscope. The moment at which the embryos reached maturity was detected by observation of the changes in their morphology.

Germination

The different tests described below were performed with 500 ml RITA tem-

porary immersion systems each containing 200 ml liquid medium. They were kept in phytotrons at 25°C ± in 40 µM.m^{-2}.s^{-1} fluorescent light with a 16-hour photoperiod and an immersion frequency of 1 min 3 times a day (Escalant *et al.* 1994).

Germination of mature somatic embryos was performed using the three procedures below.

The effect of Biobras-6 (an equivalent of brassinosteroid) on germination in semi-solid medium

The five following treatments were applied:

Treatment	Description
T1	Control (germination medium, Escalant *et al.* 1994)
T2	6-BAP + AIA + 0.005 mg/l Biobras-6
T3	6-BAP + AIA + 0.010 mg/l Biobras-6
T4	0.005 mg/l Biobras-6
T5	0.010 mg/l Biobras-6

Twenty embryos were placed in culture flasks containing 30 ml medium and kept in a growth chamber with solar light at 50 to 62.5 µM.m^{-2}.s^{-1} and at 27°C ± 2°C. Samples were chosen at random with 15 repetitions per treatment. The numbers of embryos that had formed complete plantlets were counted after 45 days of culture.

The effect of Biobras-6 on germination in RITA temporary immersion systems

The effects of two Biobras-6 concentrations (0.005 and 0.01 mg/l) were tested with the same initial embryo inoculation density (0.5 g).

The effect of the initial somatic embryo inoculum density on germination

Four initial concentrations were studied in the third protocol: 0.3, 0.5, 0.7 and 1.0 g somatic embryos in a basic MS medium complemented with 0.5 mg/l 6-BAP, 2.0 mg/l AIA and the best Biobras-6 concentration found in the preceding experiment. Three RITA were used per treatment, containing MS medium (1962) complemented with 0.5 mg/l 6-BAP, 2.0 mg/l AIA and 30 g/l sucrose, with pH 5.8.

The experiments were controlled at the same time by preparing 250 ml glass jars containing 20 somatic embryos and 30 ml semi-solid medium (Phytagel 2 g/l) of the same composition as that of the RITA preparations. Twelve repetitions were performed under the same culture conditions. All the jars and RITA preparations were placed on shelves in a growth chamber under 50-62.5 µM.m^{-2}.s^{-1} solar light and at 27°C ± 2°C. The initiation of germination was evaluated in both experiments after Day 7 of culture and the total number of plantlets formed per treatment was counted after 40 days.

As soon as plantlets appeared in the RITA preparations they were transferred to 250 ml culture flasks containing 30 ml medium containing MS salts and 3% sucrose solidified by 6 g/l agar and with pH 5.8 before autoclaving. This was performed so that they could continue growth for a further month in a culture chamber under natural light.

Comparative morphological study of plants prepared by organogenesis or somatic embryogenesis

Plantlets 4 to 5 cm tall prepared by somatic embryogenesis were weaned by planting in 50-cavity polyurethane trays in artificial substrate consisting of a mixture of casting and zeolite (3:1). They were watered by micro sprinkling for 2 min three times a day. Another batch of 200 plants obtained by *in vitro* culture of axillary buds was planted at the same time. The following quantitative characters were observed in 50 plants chosen at random in the two batches after 50 days: plant height, length and breadth of leaf 2, petiole length, distance between leaves 2 and 3 and survival percentage. Qualitative characters such as pseudostem and leaf lamina colour were also observed.

Results and discussion

Cell suspensions

Embryogenic cell suspensions of the hybrid cultivar FHIA-18 (AAAB) were generated using somatic embryos at the globular stage as the initial explant. The formation of proembryos and of small, spherical embryogenic cells with dense cytoplasm containing starch grains were observed on Day 10 of the cell suspension cultures.

Similar observations were reported by Cote *et al.* (1996) for cell suspensions prepared from male flowers of the 'Grande naine'cultivar (AAA). In the multiplication phase, these suspensions were formed of a great number of actively dividing isolated spherical cells and heterogeneous, irregular cell masses that were translucid or not. This also agrees with the observations made by De Vries *et al.* (1996) on cell suspensions of carrot. The cell characteristics above are considered to be an indicator of the embryogenic condition of the cell suspension (Williams and Maheswaram 1986). Other studies of *Musa* cell suspensions have confirmed the presence of protein bodies and starch in cells in embryogenic masses (Sannasgala 1989, Bieberach 1995).

The cell suspensions displayed changes in composition during the first two months of culture. The quantity of cell masses increased while that of isolated cells decreased to practically negligible levels. These embryogenic masses varied in size from 80 to 300 µm and finally formed 80 to 95% of the cell suspensions.

The suspensions in this culture medium also acquired a thick consistency directly related to the cell:medium volume balance.

Formation of somatic embryos

Granular structures consisting of proembryos and somatic embryos at the globular stage began to appear at the bottom of the Erlenmeyer flasks from Day 15 of culture onwards. Analysis of the results of the different inoculation densities tested for somatic embryo formation in liquid medium revealed significant differences between the different treatments on both Day 15 and Day 30 of culture.

The best results were obtained with a density of 100 mg/25ml in which 1883 globular stage somatic embryos

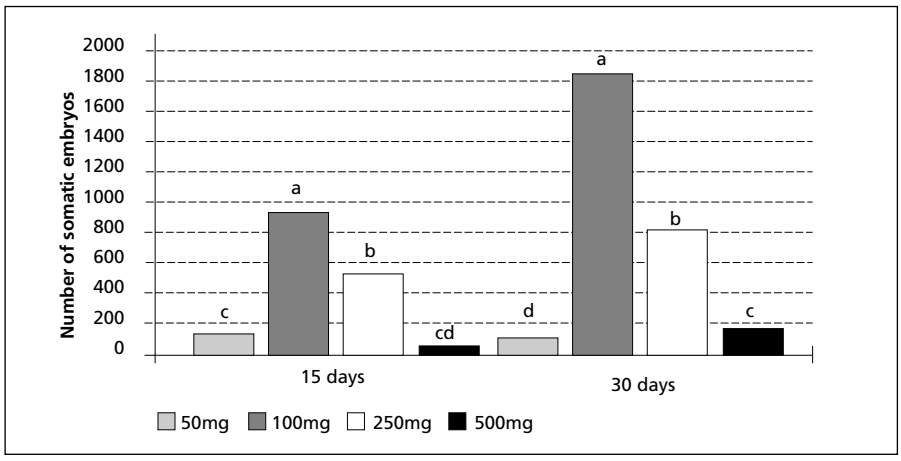


Figure 1. *Influence of inoculum density on the formation of somatic embryos of the cultivar FHIA- 18 (AAAB) after 15 and 30 days of culture.*

*different letters represent significant differences with the Duncan test, p<0.005%

formed per ml suspension in 30 days (Figure 1).

Other authors have observed even better results for the number of somatic embryos formed but on different cultivars and placing 1 ml cell suspension in a semi-solid medium (Bieberach 1995, Cote *et al.* 1996, Grapin *et al.* 1998).

The diameter of the somatic embryos obtained from cell suspensions of FHIA-18 varied from 0.5 to 1.2 mm, i.e. an average of 0.86 ± 0.25 mm. Their weight varied from 0.65 to 0.90 mg depending on the stage of development, i.e. an average of 0.73 ± 0.16 mg. Bieberach (1995) described very similar results but for other banana cultivars.

Table 1. The effect of the initial inoculation density on the multiplication of somatic embryos of the hybrid cultivar FHIA-18 (AAAB) on Day 60 of culture.

Inoculation density (g/l)	Total number of somatic embryos	Fresh weight (g)
0.2	1 200 d*	18.65 d
0.4	4 550 c	15.50 c
0.6	16 680 a	25.00 a
0.8	9 450 b	12.35 b

*different letters indicate significant differences in Dunett's (C) proof at $p < 0.05\%$.

Table 2. The effect of Biobras-6 on the germination of somatic embryos in semi-solid medium.

Treatment	Description	Number of germinated embryos	Percentage of germination
T1	Control	80	27 cd*
T2	6-BAP+AIA+0.005 mg/l Biobras-6	107	37 b
T3	6-BAP+AIA+0.010 mg/l Biobras-6	122	41 a
T4	0.005 mg/l Biobras-6	100	33 c
T5	0.010 mg/l Biobras-6	100	33 c

*different letters indicate statistically significant differences for P<5%.

Secondary multiplication of somatic embryos

It was verified that the initial concentration does have an effect on the multiplication of somatic embryos in modified MS medium as significant differences between the different treatments appeared both in fresh weight and in the number of embryos after culture for 60 days. With an initial concentration of 0.6 g:25 ml medium, the increase in fresh weight was x 42 in 60 days with the formation of a greater number of complete embryos (Table 1). This was the fist time that this had been achieved with banana in liquid medium under agitation.

It should be noted that the maturation of somatic embryos was enhanced at a lower density (0.2 g:25 ml), but that there was little multiplication. Once again, it is unnecessary to demonstrate the importance of determining an inoculation concentration adapted to each stage in the embryogenesis process.

It is important to stress that cascade embryogenesis may occur in the absence of exogenous auxin; this is referred to as auto embryogenesis, proliferation or mass propagation (Meckle *et al.* 1995). The embryos at the globular stage display cascade multiplication, each forming four to six new somatic embryos, and so on. Somatic embryos can form from the epidermal cells of the first embryo (Escalant *et al.* 1994). The process can continue indefinitely, thus enabling the multiplication of somatic embryos in bioreactors instead of using cell suspensions.

Gómez *et al.* (2000, in press) achieved cascade multiplication of somatic embryos of the cultivar Grande naine (AAA) in agitated liquid medium. These authors found that the lowest density of somatic embryos was the most effective: 0.1 g. This confirms the influence of the genotype in the *in vitro* processes and indicates the need for the development of methods suited to each cultivar studied.

Escalant *et al.* (1994) were the first to perform the secondary multiplication of somatic embryos of the cultivar Grande naine (AAA), but in a temporary immersion system. Their multiplication coefficients are very similar to those reported here. However, they reached the same level after a much longer period (six months).

Maturation of somatic embryos

Two of the initial densities studied gave good results in this experiment in agitated liquid medium. Maturation of somatic embryos was rapid at a density of 800 mg, taking only 15 days and with 30% embryos reaching full maturity. However, the synchronisation of maturation was better at a density of 400 mg since 70% of the embryos reached maturity, but later since this took 22 days.

No maturation occurred at density 1000 mg and most of the embryos remained at the globular stage. This shows the close relation between initial embryo density and the maturation process. It also shows that there is greater accumulation of reserve substances and less multiplication when low densities of some 400 mg are used, as is the case here. This phenomenon is not mentioned in the literature consulted since once they have formed, the somatic embryos at the globular stage are subcultured immediately on to a germination medium where low success rates are achieved, with a longer latency period.

Germination

The effect of Biobras-6 in semi-solid culture medium

It was observed in this first experiment that the largest quantity of embryos germinated in treatments T2 and T3 combining Biobras-6, AIA and 6-BAP, as these treatments displayed significant differences in comparison with the other treatments and the control. Their germination percentages were 37 and 41% respectively. These results demonstrate the stimulating effect of Biobras-6 on germination (Table 2) when this acts in synergy with the mixture of regulators aimed at enhancing germination. The best treatment is T3, where 0.01 mg/l Biobras-6 was added. Work on callogenesis by Rayas *et al.* (1999) shows that DAA-6 (Biobras-6) and MH-5, two substances similar to brassinosteroid, also had a favourable effect on callus growth and quality, in particular with concentrations of 0.01 mg/l Biobras-6 and 0.1 mg/l MH-5. Comparison of the germination of somatic embryos in semi-solid medium with that in a temporary immersion system shows that the latter process is more effective with regard to both latency time and germination percentage.

The effect of Biobras-6 on the germination of somatic embryos with the RITA temporary immersion system

The results of this second experiment, in which somatic embryos were set to germinate using the RITA temporary immersion system, reveal a higher germination percentage and significant differences to the other treatments when a Biobras-6 concentration of 0.01 mg/l was used. The number of embryos that germinated in this treatment attained 600, making a germination percentage of 85%, which is 15% higher than that achieved without Biobras-6 (Figure 2).

The use of Biobras-6 in *in vitro* culture has already given good results for the germination of papaya somatic embryos (Posada 1995). According to

Nuñez (1996), brassinosteroids display strong synergy with auxins. They can also act with gibberellins either as auxins or as gibberellins or cytokinins.

Comparison of the temporary immersion system with the preceding test on semi-solid medium shows that temporary immersion combined with the regulatory action of Biobras resulted in a positive improvement of the ontogenesis of somatic embryos.

Indeed, bud formation is one of the major difficulties in the somatic embryogenesis of many species, including conifers (Tautorus *et al.* 1992, Lelu *et al.* 1994) and rubber tree (Michaux-Ferrière *et al.* 1992, Etienne *et al.* 1997). This obstacle can be overcome by the use of temporary immersion systems. The positive impact of this type of treatment seems to be related to the way in which the liquid medium is used. Indeed, it combines the advantages of permanent immersion, avoiding the problems of vitrification and lack of oxygen, and those of partial immersion on inert support (Roberts and Smith 1990) by mitigating absorption inefficiency and reducing handling operations.

In temporary immersion systems, the entire surface of the plant material is in uniform contact with the nutrients of the medium, even when it is not immersed since a fine coating of medium adheres to the plant tissue by capillary attraction. This coating is insufficient to inhibit gas exchanges and the chemical composition is renewed at each immersion. Aeration is also improved as each immersion also regenerates the ambient medium (Teisson and Alvard 1995). In addition, short agitation of the plant material occurs. All these features have enabled the germination of somatic embryos of various species (*Citrus, Musa, Coffeae*) that was hitherto impossible in Erlenmeyer flasks or bioreactors (Teisson and Alvard 1995), as the latter are more complex, more difficult to handle and more expensive than RITA (Etienne *et al.* 1997).

It should be noted that the use of RITA systems has also made it possible to prevent the oxidation of somatic embryos of the cultivar FHIA-18 (AAAB). Bieberach (1995) reports similar results on other cultivars, most of whose somatic embryos started to germinate on Day 7 of culture. The same phenomenon has also been observed with other temporary immersion systems consisting of 10 l recipients (Nalgène company) in which 65.5 to 73% of embryos (500 to 800 per recipient) germinated (Gómez, unpublished data).

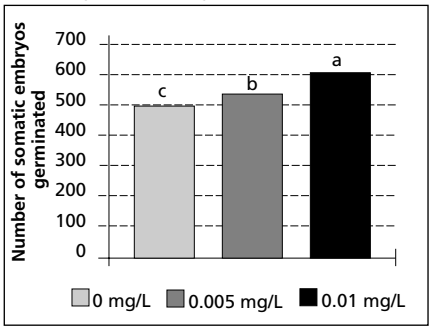
Temporary immersion systems thus enhance more substantial, synchronised development of somatic embryos, also described by Etienne *et al.* (1997) on *Hevea brasiliensis* (Mull Arg) and by Cabasson *et al.* (1997) on *Citrus deliciosa* (Ten).

Table 3. Effect of the initial inoculation density on the germination of somatic embryos of the hybrid cultivar FHIA-18 (AAAB) on Day 30 of culture.

Inoculation density (g)	Initial number of embryos	Number of germinated embryos (X+ ET)	Percentage of germination
0.3	750	320 ±14.1	45 b*
0.5	750	600 ±16.7	85 a
0.7	1 050	402 ±14.3	26 bc
1.0	1 500	260 ±12.3	17 c
Control	300	43 ±7.71	14 c

*different letters indicate significant differences in Dunett's (C) proof at p < 0.05%.

Figure 2. *The effect of Biobras-6 on the germination of somatic embryos in the RITA temporary immersion system.*



*different letters indicate statistically significant differences for P<5%.

The effect of the initial inoculation density of somatic embryos on germination in the RITA temporary immersion system

The best density is 0.5 g, at which the best germination percentage (85%) was observed. The percentages are far higher than that of the control in all cases (Table 3). They are some of the highest figures ever attained for the germination of somatic embryos of banana and plantain. This may be the result of various factors, including the positive effects of temporary immersion and the previously described favourable effects of the regulator Biobras-6 and, of course, the genotype. No specific information has hitherto been reported concerning the germination of somatic embryos of the hybrid cultivar FHIA-18 (AAAB).

Known germination percentages of somatic embryos of the genus *Musa* vary between 0.45 and 80% according to the genotype and the culture medium (Bieberach 1995, Cote *et al.* 1996, Schoof 1997, Grapin *et al.* 1998).

The highest germination percentages obtained to date are those of Escalant *et al.* (1994), who also used temporary immersion systems but on other banana cultivars.

Comparative morphological study of plants resulting from organogenesis and those being weaned after somatic embryogenesis

The results do not show any differences between the two batches of plants produced by organogenesis or somatic embryogenesis except in the larger size of those of embryogenic origin (Table 4). In addition, no off-types, such as dwarf, giant or mosaic variants, were observed (Sandoval *et al.* 1997). These results agree with those of Cote *et al.* (1999) who worked on cell suspensions of the cultivar Grande naine (AAA) and compared plants produced using this technique with those produced by traditional organogenesis; they did not find any morphological differences in the field.

This does not mean that there were no somaclonal variations, but simply that it was not possible to detect them at this stage of development. Sandoval *et al.* (1997) pointed out that in any case at this stage it is only possible to detect approximately 60% of somaclonal variations. They therefore suggest that field evaluation should be continued to cover the development cycle for several generations. In addition, Schoof (1999) reported up to 97% somaclonal variations in 'Williams'plants produced from cell

Table 4. Comparison of plants of the hybrid cultivar FHIA-18 (AAAB) obtained either by somatic embryogenesis or by organogenesis.

Type of morphogenesis	Petiole length (cm)	Length of leaf 2 (cm)	Width of leaf 2 (cm)	Distance between leaves 2 and 3 (cm)	Plant height (cm)
Organogenesis (axillary buds)	1.95± 0.19 a*	13.22± 0.7 a	6.68± 0.6 a	1.90± 0.2 a	6.60± 0.4 b
Somatic embryogenesis 7.30± 0.6 a		1.86± 0.12 a	13.90±. 62 a	7.10± 0.4 a	1.91± 0.2 a
Average ± ET	**1.90 ± 0.15**	**13.55 ± 0.67**	**6.90 ± 0.53**	**1.9 ± 0.2**	**6.95 ± 0.54**
CV	**0.13**	**0.21**	**0.13**	**0.15**	**0.3**

*Different letters represent significant differences at P< 5%.

suspensions; the variations apparently resulted from the «scalp» technique in which very strong 6-BAP concentrations are used. Research at the Laboratory Tropical Crops Improvement at Catholic University of Leuven (KUL) showed 100% somaclonal variation in plants produced from cell suspensions of the cultivar Grande naine (AAA); the most common variations after 6 months were dwarfism and thick, distorted leaves (INIBAP 1997).

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Rafael Gomez Kosky and **Maritza Reyes** work at the *Instituto de Biotecnología de las Plantas, Universidad Central de Las Villas*, Santa Clara, Cuba, email: rgkosky@uclv.etecsa.cu; **Terrence Gilliard** at the *Ministerio de Agricultura de Santa Lucia* and **Luis Antonio Barranco** at the *Universidad de Las Tunas*, Las Tunas, Cuba.

Improvement | **Induced variability**

Improvement of the hybrid plantain clone FHIA-21 by mutagenesis *in vitro*

I. Bermúdez, P. Orellana P., J. Pérez Ponce, J. Clavero, N. Veitía, C. Romero, R. Mujica and L. García R.

Black Sigatoka (*Mycosphaerella fijiensis* Morelet) is currently the most destructive disease in the world for bananas and plantains. Since it appeared in Cuba in November 1990, it has become the most widespread fungal disease in the plantations in the island.

The best solution for reducing the damage caused by this devastating disease is the breeding of resistant varieties. Since 1984, the FHIA (*Fundación Hondureña de Investigación Agrícola*) has developed a vast research programme on resistant hybrids, which include 'French Plantain' FHIA-21 (AAAB), which is resistant to wilt, gives fruits of good size and quality enabling good yields, but whose habit is too tall.

The use of mutagenic agents combined with biotechnology techniques makes it possible to intensify genetic variability in order to improve certain

agronomic characters such as fructification, yield, quality and resistance to pathogens and diseases (Ho *et al.* 1993, 1994). In addition, tissue culture techniques facilitate the induction, breeding and dissemination of mutants.

In vitro shoot tip culture has been used to induce mutations in several *Musa* genotypes with different ploidy levels and different combinations of genomes of *acuminata* (A) and *balbisiana* (B) (Novak *et al.* 1986).

The work presented here was performed within the framework of biotechnology applied to genetic improvement, with the following objectives:

- the breeding of short stature somaclonal variants among irradiated populations of the clone FHIA-21,
- the study of behaviour with regard to black Sigatoka.

Material and methods

Germplasm was delivered to the laboratory for subsequent *in vitro* multiplication using the protocol described by Orellana *et al.* (1991). The formation of multiple buds was induced by placing shoot tips in an MS medium (1962) complemented by 6-benzyl aminopurine (6-BAP) 20 mg/l, indolacetic acid (AIA) 0.65 mg/l and sucrose 30 g/l at pH 5.8. To induce variability, the buds were subjected to 25 Gy gamma radiation derived from the disintegration of C^{60}. Five subcultures were then performed to regenerate approximately 10,000 tissue culture plants that were hardened off in the greenhouse for 45 days before being transplanted in the field at Remedios experimental station. Minimum agricultural work was performed throughout the development of the plantation, without the application of fungicides, so that the response of plants to natural pressures could be observed.

Evaluations consisted of selecting plants with positive characters in the field and studying the variability of the population. Records were made of plant height (with three categories), pseudostem girth, total leaves, the number of spotted (BS) leaves at bunch formation and then at harvesting, the number of hands and fingers of the bunches (three categories) and the length of the central finger of the second and penultimate hands. The lines with positive characteristics were planted at five plants per row at the same experimental station to perform a clone study with comparison with the original clone. The most promising lines were transferred *in vitro* in order to increase the population for study in other environments.

The work was performed as in the diagram below (Figure 1):

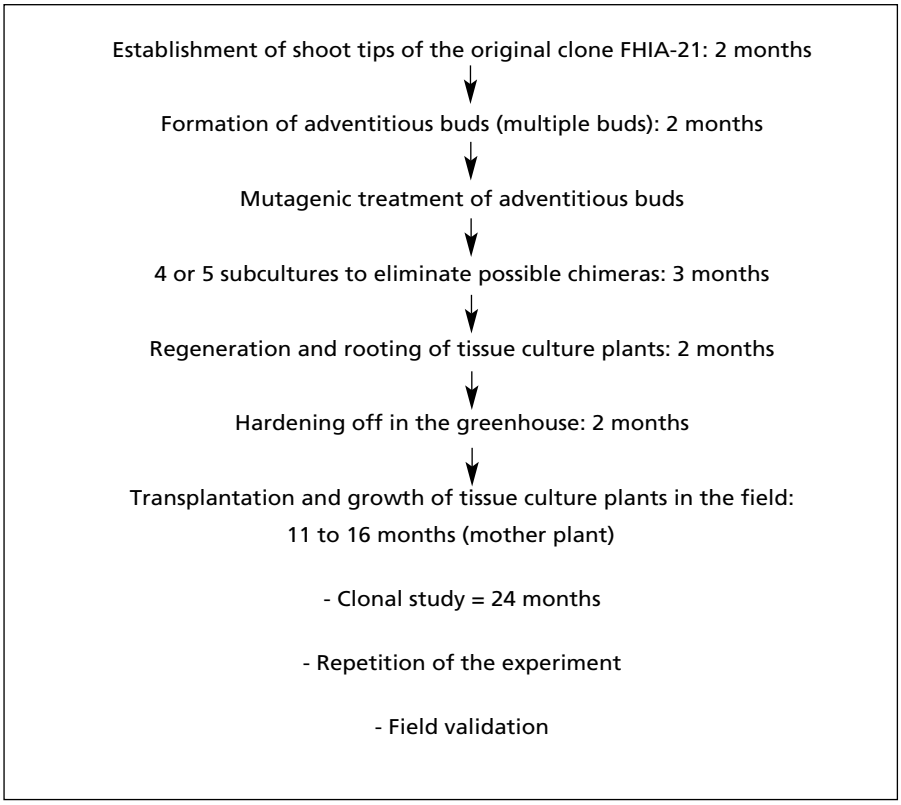

Figure 1. *Diagram of the improvement of the hybrid FHIA-21 by mutation.*

Results and discussion

Evaluation revealed considerable variability in the plant material with regard to plant height, pseudostem diameter, total number of leaves, changes in bunch level and impact of Black Sigatoka, clearly showing the effectiveness of the combination of mutagen and tissue culture. Novak *et al.* (1990) obtained similar results in an improvement programme with mutation of clones of the genus *Musa*.

A high degree of variation in plant height was observed in particular, as is shown in Table 1:

The results in Table 1 show that the environment has a marked influence on both populations. Indeed, the normal height of the original clone FHIA-21 varies from 250 to 300 cm in the first reproduction cycle. In addition, the smallest plants in the irradiated batch included several variants with other favourable changes such as finger size, bunch shape and leaf structure that differ considerably from the original clone. The aim of this work was not only to seek low plants but also to take into account all the other positive characters since the frequencies of variation in height were very similar on both the selected and non-selected irradiated batches. It is also important to underline that in the first cycle, many banana and plantain clones do not attain the height reached in subsequent cycles.

Considerable variation in the number of fingers was also noted (Table 2) in the entire population in which 59.86% of plants bore bunches with over 60 fingers. This frequency was maintained in the selected plants (57.1%).

Many authors have noticed that the frequency of phenotypic and/or morphological variations (plant height,

Table 1. Variation in plant height during the first reproduction cycle.

Height categories (cm)	Number of plants selected	Frequency of variation (%)
Selected irradiated material		
100-250	41	38.30
251-300	61	57.00
>300	5	4.70
Total	**107**	**100.00**
Non-selected irradiated material		
100-250	103	35.76
251-300	169	58.68
>300	6	5.55
Total	**288**	**100.00**

Table 2. Variation in the number of fingers per bunch during the first cycle.

Variation in the number of fingers	Number of plants	Frequency (%)
Selected irradiated material		
up to 40 fingers	21	20.00
41 to 60 fingers	24	22.80
over 60 fingers	60	57.10
Non-selected irradiated material		
up to 40 fingers	16	10.08
from 41 to 60 fingers	43	29.25
over 60 fingers	88	59.86

Table 3. Phenotypic variations observed in comparison with the original clone in plants selected during the first cycle.

Number of plants observed	Low habit; False Horn type possible	Longest fingers	Short, slender fingers	Small, straight fingers	High resistance to black Sigatoka	Total frequency (%)
1024	4	10	20	12	3	4.78

Table 4. Average and deviations between observations according to the population.

	Average				Deviation			
Population	**Height (cm)**	**Pseudo-stem girth (cm)**	**Number of hands**	**Number of fingers**	**Height (cm)**	**Pseudo-stem girth (cm)**	**Number of hands**	**Number of fingers**
Non-selected irradiated material	270.71	48.48	6.61	68.78	25.40	6.29	6.19	18.83
Selected irradiated material	250.44	47.91	6.40	67.59	25.94	5.25	1.04	20.78

leaf colour), physiological variations (growth and sucker multiplication, duration of flowering, fruit ripening) and agronomic variations (bunch qualities) varies from 3 to 40% in the first generation plants according to their genotype and the radiation doses applied (Novak *et al.* 1990).

Phenotypic variation frequency in the 1024 first plants observed was 4.78%. They reveal four somaclonal variants that could be the False Horn type, although two of them are susceptible to black Sigatoka (Table 3).

Comparison of the average values and the deviations between the observations of the selected population and those of the total population shows that the latter is taller than the selected population (Table 4). In contrast, an average of about six hands per bunch was observed in both cases. The plants also had an average of more than 60 fingers per bunch in most cases. This confirms the positive correlation between plant height and the total number of fingers per bunch.

Analysis of population deviations shows that the most variable parameters are height and number of fingers, as has already been reported.

Five of the selected plants display the best profile with a combination of different characters (Table 5) and varied reactions to black Sigatoka.

Significant differences in plant height were observed between the lines themselves and also between the lines and the original clone FHIA-21. Lines IBP 24-14 and IBP 47-4 display the lowest values. However, the latter also have poorer results than the other lines and the control with regard to several important agronomic characters (number of fingers per bunch, bunch weight). In addition, their bunches are of the False Horn type whereas those of the others and the control have French type bunches. In contrast, lines IBP 14-23 and IBP 17-13, whose heights are significantly lower than the control FHIA-21, display good agronomic behaviour in the other yield indicators. This makes them very promising for the selection of short plants in this hybrid.

It should be stressed that the control FHIA-21 suffered a strong generalised black Sigatoka attack and could not produce completely developed fingers, which is in contradiction with reports that concluded that it has high resistance (Cote *et al.* 1994).

Conclusions

The general frequency of variation of irradiated hybrid FHIA-21 material was 4.78% during the first cycle (mother plant). The most variable characters are plant height and the number of fingers per bunch, among other morphological variations. The most stable characters are pseudostem diameter and the number of hands per bunch.

Although the hybrid FHIA-21 bears a French type bunch, several variants were observed that produced False Horn type bunches whose general morphology is very different to the original clone.

Most of the population studied was strongly affected by black Sigatoka even though plants that had reached harvest with more than three active leaves were selected. ■

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Table 5. Growth parameters evaluated in the selected lines.

Code of the line	Plant height (cm)	Pseudo stem girth (cm)	TLF*	TLH**	Planting to harvest (months)	Number of fingers	Bunch weight (kg)	Girth of central finger*** (cm)	External length of central finger (cm)
IBP 14-23	281.6**b**	54.2**a**	12.0**a**	6.2**b**	11.6**c**	83.2**b**	14.08**b**	3.4**a**	22.8**a**
IBP 17-13	282.5**b**	47.5**b**	10.5**ab**	9.0**a**	13.0**a**	64.0**c**	14.5**b**	2.75**bc**	20.0**a**
IBP 50-5	294.8**ab**	57.4**a**	11.4**ab**	4.6**b**	11.6**c**	100.0**a**	21.08**a**	3.40**a**	23.6**a**
IBP 24-14	236.0**c**	45.4**b**	9.4**b**	5.0**b**	13.0**a**	45.0**d**	5.15**c**	3.1**abc**	19.6**a**
IBP 47-4	215.0**d**	36.8**c**	7.0**c**	4.4**b**	12.8**ab**	57.2**cd**	5.98**c**	2.62**c**	19.6**a**
(FHIA-21) Control	302.8**a**	56.6**a**	9.8**ab**	6.6**b**	11.8**bc**	105**a**	13.8**b**	3.32**ab**	22.0**a**
Deviation (x)	±0.26	±0.14	±0.67	±0.69	±0.30	±0.69	±0.45	±0.16	±0.90

* TLF: Total leaves at flowering ; ** TLH: Total leaves at harvesting ; *** Central finger of the central hand.
Identical letters in the same column indicate that there is no significant difference at P<0.05.

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The authors work at the *'Instituto de Biotecnología de Las Plantas* (IBP), UCLV, Santa Clara, Villa Clara, Cuba.

Evaluation of *Musa* spp. for resistance to Moko disease (*Ralstonia solanacearum*, race 2)

S. de Oliveira e Silva, S. de Mello Véras, L. Gasparotto, A. Pires de Matos, Z. Maciel Cordeiro, and B. Boher

The Moko disease of banana, caused by *Ralstonia (Pseudomonas) solanacearum* race 2 (Smith), induces wilting of the leaves, starting from the young ones, and necrosis of the candle leaf as well. Immature fruits of infected plants show yellowish color and dry rot of the pulp. Early infection, prior to flowering, causes abnormal development of the bunch, fruit rot before ripening, and some plants may not yield a bunch. The Moko disease can be disseminated either by insects, through infested soil or by root contact. These characteristics associated with unavailability of resistant cultivars and low production technology make the Moko disease a very serious problem for the banana crop (Buddenhagen 1961, Stover 1972, Takatsu 1986, Matos *et al.* 1996).

R. solanacearum, race 2, was first reported in Brazil in the Amazon Region, State of Amapá (Tokeshi 1976). Currently this disease is also present in the States of Amazonas, Para and Acre, all of them located in the Amazon Region (Takatsu 1986). According to diagnostic surveys the number of banana orchards affected by the A strain of *R. solanacearum*, race 2, in the Amazon Region has been increasing in the past years (Matos *et al.* 1996, Pereira *et al.* 1997).

Several recessive genes are involved on the banana resistance to Moko (Vakilii 1965, Rowe and Richardson 1975). Results reported by Stover (1972) showed several levels of susceptibility to Moko in banana cultivars, pointing out that the cultivar Pelipita (ABB) is highly resistant to the pathogen, thus indicating the genetic resistance as a viable control measure for Moko in regions where the banana crop is grown under very low production technology (Jones 1995).

Despite that possibility, no Moko-resistant germplasm was found when tetraploids (AAAB), such as PV03-44, JV03-15, PA03-22, Pioneira; triploids (AAA) Caipira, Nam, Nanica and Nanic‹o, (AAB) Pacovan, Prata, Prata An‹, Mysore, Thap Maeo and Ouro da Mata; and plantains (AAB) Pacovi, Pacovan and Bluggoe, (ABB) Figo, were planted in naturally infested soil (Silva *et al.* 1998).

The objective of this paper was to evaluate the reaction of 31 diploid (AA) genotypes to the inoculation with *R. solanacearum*, race 2, aiming at selecting resistant ones to be used as male parents in the banana breeding programme under conduction at the Embrapa Cassava and Fruit Crops (CNPMF).

Material and methods

A total of 31 diploids (AA) genotypes - 21 natural germplasm and 10 hybrids - from the Banana Germplasm Bank of CNPMF, Cruz das Almas, State of Bahia, were evaluated. The experiment was carried out under greenhouse conditions, at the Embrapa Occidental Amazon (CPAA), located in the municipality of Manaus, Amazonas, North of Brazil, where the Moko disease is endemic.

Eight plants of each diploid (AA) genotype were inoculated with the Biovar 1 of *R. solanacearum*, race 2, by injecting 1mL of a bacterial suspension, at a concentration of 10^8 CFU.mL^{-1}, into the pseudostem, at 10 cm from the soil level.

External symptoms were evaluated at weekly intervals, based upon the following disease rating scale:

- No symptoms
- Necrosis of the candle leaf
- Yellowing of 2-3 leaves
- Buckle of the petiole
- Death of the plant

Plants without symptoms eight weeks after inoculation were considered resistant to Moko disease.

Results and discussion

Six weeks after inoculation the plants started showing external symptoms characteristics of the Moko disease. All plants that expressed external symptoms also showed vascular discoloration characteristic of infection by *R. solanaceraum*, race 2. These results indicate the efficiency of the inoculation technique used to evaluated diploid (AA) banana genotypes.

The natural germplasm Berlin, Buitenzorg, Fako Fako, Jambi, Jaran, Jari Buaya, Khai, Khi Maeo, Lidi, Microcarpa, NBA 14, NBF 9, N⁄118, Ouro, P. Serum, Pipit, Pa Phathalung, Tongat, Tambi and Zebrina and the hybrids 1304-04, 1318-01, 4223-06, F3P4, M-48 and M-61 showed susceptible reaction to the Biovar 1 of *R. solanacearum*, race 2. On the other hand, the diploid (AA) hybrids F2P2, 1319-01, 1741-01 and SH3362, and Babi Yadefana, a diploid cultivar from New Guinea, expressed resistance to the pathogen. Some characteristics of the five Moko-resistant genotypes are presented in Table 1.

Although resistance to Moko disease has not been detected in triploid and tetraploid commercial varieties so far (Vakilii 1965, Silva *et al.* 1998), the results presented in this paper show the occurrence of genetic variability among diploid (AA) banana genotypes able to express resistance to *R. solanacearum*, race 2.

The detection of resistance to Moko disease in diploid (AA) genotypes

Table 1. Some characteristics of diploids (AA) banana genotypes resistant to Moko disease. Embrapa Occidental Amazon, Manaus, Amazonas, Brazil, 1998.

Genotype[1]	Height	Fruits /bunch	Length of fingers (cm)	Reaction to diseases[2]		
				Fusarium wilt	Yellow Sigatoka	Black Sigatoka
Babi Yadefana	Low	60	12	_	S	-
F_2P_2	Medium	96	12	-	-	-
1319-01	Medium	200	13	R	R	
1741-01	Medium	112	14	-	R	-
SH3362	High	192	15	-	-	S

[1] Babi Yadefana: cultivar from New Guinea; F_2P_2: hybrid from Ecuador; 1319-01: cross between Malaccensis x Tjau Lagada, selection 01; 1741-01: cross between Jary Buaya x hybrid (Calcutta x Madang); SH3362: hybrid from Honduras.
[2] R: resistant; S: susceptible.

opens up a real possibility of creating resistant commercial varieties, through conventional breeding techniques. Considering that only a small number of genotypes was evaluated, it is expected that new sources of resistance to *R. solanacearum*, race 2 would be detected as evaluations continue. ■

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S. de Oliveira e Silva, **A. Pires de Matos** and **Z.J. Maciel Cordeiro** are Plant Breeder and Plant Pathologists, respectively at Embrapa Mandicoa e Fruticultura, C. Postal 007, CEP 44380 000, Cruz das Almas, BA, Brazil. e-mail of first author ssilva@cnpmf.embrapa.br, **S. de Mello Véras** is located at Embrapa/CNPq, C. Postal 219, CEP 69048.660, Manaus, AM, Brazil. **L. Gasparotto** is Plant Pathologist at Embrapa Amazonia Occidental, C. Postal 219, CEP 69048.660, Manaus, AM, Brazil and **B. Boher** is Agronomist at INPA, C. Postal, 478, CEP 69011-970, Manaus, AM, Brazil.

Multilocational evaluation of FHIA hybrids in Ghana

B.M. Dzomeku, B. Banful, A.A. Ankoma, D. Yeboah and S.K. Darkey

Plantain and banana (*Musa* spp.) are very important starchy staples in Ghana. They are consumed both as energy-yielding food and as dessert. Plantain contributes about 13.1% of the Agricultural Gross Domestic product and its *per capita* annual consumption of 85 kg per head is higher than other staples such as maize and yam. Plantain and banana are also very important sources of rural income (Ortiz and Vuylsteke 1996).

Despite their high value, production has been affected by growing pest and disease pressures, the most notable being the fungal disease black Sigatoka *(Mycosphaerella fijiensis*). The disease was first observed at Assin-Fosu in the Central region of Ghana in the early 1980s and has since spread to all the plantain-growing regions of the country. Yield losses due to the disease are highly significant, ranging from 20 to 50%. Under very severe conditions yield losses may be as high as 80% (Hemeng and Banful 1994).

The black Sigatoka disease can be controlled with appropriate fungicides but the cost is prohibitive. Furthermore, the fungicides are not environmentally-friendly and thus threaten the fragile ecosystem. Consequently, the best viable alternative for the control of black Sigatoka is through the use of high-yielding resistant hybrids.

The Crops Research Institute introduced in 1994 some black Sigatoka-resistant/tolerant tetraploid hybrids of *Musa* from *Fundación Hondureña de Investigación Agrícola* (FHIA) in Honduras. The introduction was against the background that all the local landraces are susceptible to black Sigatoka disease. The hybrids included one dessert banana (FHIA-01), one cooking banana (FHIA-03) and one French plantain (FHIA-21).

Materials and methods

Tissue culture plantlets of FHIA-21 and FHIA-01 were received from the *Fundación Hondureña de Investigación Agrícola* (FHIA) in Honduras for evaluation. The plantlets were hardened under a hardening shed for six weeks before field planting.

The trials were established at three locations, namely Fumesua in the Ashanti region, Assin-Fosu in the Central region and Bunso in the eastern region. The locations were selected on the basis of the variation in the soil types and the severity of black Sigatoka incidence. The design was a randomized complete block with three replications. Three kilograms of poultry manure were applied as soil amendment at planting. The planting spacing was 3 m x 2 m (1667 plants/ha).

The disease evaluation was carried out using the Stover scale of 1 to 10 as observed on the third leaf.

Table 1. Yield and selected agronomic parameters of FHIA–21 at harvest (Fumesua, Bunso and Assin-Fosu)

	Fumesua				Bunso				Assin Fosu			
	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE
Plant height at harvest (cm)	270.0	268.2	269.0	**269.1 (0.2)**	247.0	258.0	256.4	**253.8 (7.8)**	238.8	244.0	239.0	**240.6 (1.9)**
Height of tallest daughter sucker (cm)	195.0	156.0	148.0	**166.3 (140.5)**	135.0	125.0	115.5	**121.5 (21.1)**	145.0	134.0	136.2	**138.4 (7.5)**
Number of daughter suckers	4.0	4.0	6.0	**4.7 (0.3)**	4.0	5.0	4.0	**4.5 (0.1)**	2.8	5.0	4.0	**3.9 (0.3)**
Number of leaves at flowering	14.0	13.0	12.0	**13.7 (0.2)**	12.0	13.0	14.0	**13.0 (0.2)**	11.3	13.0	14.0	**12.8 (0.4)**
Number of leaves at harvest	6.0	7.0	6.0	**6.3 (0.1)**	8.0	8.0	7.0	**7.8 (0.1)**	8.0	7.0	7.0	**7.3 (0.1)**
Yield (t/ha)	41.7	38.4	39.2	**39.8 (0.7)**	30.3	32.4	35.7	**33.7 (1.6)**	35.3	37.4	38.5	**37.1 (0.6)**
Pseudostem (cm)	55.0	56.0	55.2	**55.4 (0.1)**	57.0	55.0	44.0	**49.8 (10.9)**	53.8	51.6	47.3	**50.9 (2.4)**
Number of months to flowering	11.4	11.6	11.3	**11.4 (0.0)**	11.5	11.3	11.8	**11.5 (0.0)**	11.1	11.4	11.3	**11.3 (0.0)**
Number of months to harvest	14.9	15.3	15.1	**15.1 (0.0)**	15.2	14.9	15.2	**15.1 (0.0)**	14.5	14.8	14.7	**14.7 (0.0)**
Number of hands/bunch	8.0	7.0	8.0	**7.7 (0.1)**	8.0	7.0	8.0	**7.7 (0.1)**	7.0	8.0	7.0	**7.3 (0.1)**
Number of fingers	108.0	98.0	115.0	**107.0 (16.2)**	99.0	100.0	101.0	**100.0 (0.2)**	98.0	99.0	97.0	**98.0 (0.2)**

Table 2. Yield and selected agronomic parameters of FHIA –01 at harvest between 1997-1999 at Fumesua, Bunso and Assin-Fosu.

	Fumesua				Bunso				Assin Fosu			
	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE
Plant height at harvest (cm)	237.0	241.0	240.0	**239.3 (1.0)**	265.0	250.0	248.2	**254.4 (18.9)**	245.0	240.0	250.1	**245.0 (5.7)**
Height of tallest daughter sucker (cm)	180.0	170.0	168.0	**172.7 (9.2)**	180.0	172.3	167.4	**173.2 (9.0)**	120.0	128.0	118.0	**122.2 (5.7)**
Number of daughter suckers	3.2	5.0	6.3	**4.8 (0.5)**	5.2	6.1	4.0	**5.1 (0.2)**	3.0	6.0	4.0	**4.3 (0.5)**
Number of leaves at flowering	13.0	14.0	14.0	**13.7 (0.1)**	14.2	13.0	13.0	**13.4 (0.1)**	14.0	13.0	13.0	**13.3 (0.1)**
Number of leaves at harvest	7.0	8.0	7.0	**7.3 (0.1)**	5.6	7.0	8.0	**6.9 (0.3)**	6.0	8.0	7.0	**7.0 (0.2)**
Yield (t/ha)	38.3	40.8	41.1	**40.1 (0.5)**	42.7	39.4	38.5	**40.2 (1.0)**	30.7	34.2	55.6	**33.1 (1.4)**
Pseudostem (cm)	50.3	49.3	50.2	**49.9 (0.1)**	50.6	47.3	49.0	**49.0 (0.6)**	45.0	48.5	46.2	**46.6 (0.7)**
Number of months to flowering	11.3	11.4	11.3	**11.3 (0.0)**	11.3	11.3	11.4	**11.3 (0.0)**	11.9	11.4	11.6	**11.6 (0.0)**
Number of months to harvest	14.7	14.5	14.7	**14.6 (0.0)**	15.0	15.2	15.0	**15.1 (0.0)**	15.4	15.2	15.3	**15.3 (0.0)**
Number of hands/bunch	8.0	8.0	8.0	**8.0 (0.0)**	8.0	9.0	8.0	**3.0 (0.1)**	7.0	8.0	7.0	**7.3 (0.2)**
Number of fingers	109.0	103.0	112	**108.0 (4.7)**	110.0	102.0	104.0	**105.3 (3.9)**	101.0	98.0	99.0	**99.3 (0.5)**

Table 3. Yield and selected agronomic parameters of FHIA–03 at harvest between 1997-1999 at Fumesua, Bunso and Assin-Fosu.

	Fumesua				Bunso				Assin Fosu			
	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE	1997	1998	1999	Mean SE
Plant height at harvest (cm)	225.0	221.0	220.0	**222.0 (1.5)**	226.0	230.0	228.2	**228.1 (1.9)**	235.0	233.0	230.1	**232.7 (1.4)**
Height of tallest daughter sucker (cm)	100.0	98.0	102.0	**100.0 (0.8)**	100.0	107.3	115.4	**107.6 (4.4)**	90.0	99.0	101.0	**96.7 (7.6)**
Number of daughter suckers	3.0	3.2	4.0	**3.4 (0.1)**	1.0	1.0	1.0	**1.0 (0.0)**	2.0	2.0	3.0	**2.3 (0.1)**
Number of leaves at flowering	12.4	12.0	11.0	**11.8 (0.1)**	14.0	14.0	13.0	**13.7 (0.0)**	10.0	11.0	11.0	**10.7 (0.1)**
Number of leaves at harvest	8.0	7.0	6.0	**7.0 (0.2)**	6.3	6.0	6.0	**6.1 (0.0)**	5.0	4.0	6.0	**5.0 (0.2)**
Yield (t/ha)	38.3	36.8	36.1	**37.1 (0.3)**	34.3	34.0	34.5	**34.2 (0.0)**	25.3	26.4	27.8	**26.5 (0.3)**
Pseudostem (cm)	58.0	56.0	58.0	**57.3 (0.3)**	60.0	58.0	60.0	**59.3 (0.3)**	53.0	52.0	53.0	**52.7 (0.1)**
Number of months to flowering	8.0	7.8	7.9	**7.9 (0.0)**	8.6	8.7	8.5	**8.6 (0.0)**	8.6	8.3	8.0	**8.3 (0.6)**
Number of months to harvest	11.0	10.7	11.0	**10.9 (0.0)**	11.6	11.7	11.5	**11.6 (0.0)**	11.6	11.2	11.0	**11.4 (0.0)**
Number of hands/bunch	8.0	7.0	8.0	**8.0 (0.0)**	8.0	7.0	8.0	**7.7 (0.1)**	7.0	8.0	7.0	**7.3 (0.2)**
Number of fingers	92.0	90.0	94.0	**92.0 (1.3)**	91.0	90.0	93.0	**91.3 (0.9)**	93.0	90.0	92.0	**91.7 (0.9)**

Table 4. Comparison of yield and selected agronomic parameters of FHIA-21 with two French plantain landraces at Assin Fosu and Bunso.

	1997				1998			
	FHIA-21	Apem Pa	Apem oniaba	SE	FHIA-21	Apem pa	Apem oniaba	SE
Plant height at harvest (cm)	252.3	352.0	273.0	30.4	256.0	353.0	272.0	30.0
Pseudostem girth (cm)	54.7	59.2	47.1	3.3	49.7	57.5	50.3	2.5
Number of daughter suckers	5.3	4.5	7.0	0.7	4.7	4.0	6.0	0.6
Number of leaves at flowering	12.1	10.0	8.0	1.2	13.3	11.0	9.0	1.2
Number of leaves at harvest	7.3	4.0	1.0	1.8	7.0	4.0	2.0	1.5
Number of months to harvest	14.8	18.0	16.2	0.9	15.0	18.5	17.0	1.0
Number of hands/bunch	7.3	8.0	6.0	0.5	8.0	8.0	6.0	0.6
Number of fingers/bunch	101.0	109.0	98.0	0.5	100.0	111.0	100.0	0.7
Yield (t/ha)	35.7	24.0	15.8	5.7	36.5	25.3	16.3	5.8

Results and discussion

At each of the three locations, FHIA–21 exhibited stable performance in yield and growth characteristics over the three years of study (Table 1). The performance of FHIA-21 in yield and growth characteristics over the years in all three locations was consistent and suggested its stability. Similar trends were observed in FHIA-01 (Table 2). These results suggested that performance of FHIA–21 and FHIA-01 was not influenced by seasons or locations. It implies that under good management practices, farmers would be assured of good yields irrespective of time or season of planting so long as there is adequate supply of moisture.

FHIA-03 (cooking banana) showed consistency in yield and growth performance over the years (Table 3). The agronomic characteristics of the hybrid were not affected by location. The hybrid was however not well accepted by consumers.

Comparing the performance of FHIA-21 with the land races Apem pa and Apem oniaba, FHIA-21 exhibited superiority in growth and yield for all the locations tested (Table 4). FHIA-21 was 21% shorter in height and 8% thicker in pseudostem girth than the mean of the landraces, which suggested that plants of FHIA-21 were sturdier than the landraces. It is therefore more likely that FHIA-21 would escape stem lodging. Earlier work (Hemeng *et al.* 1994) indicated that plants with thicker pseudostem girth experienced less stem lodging. FHIA-21 also retained more functional leaves at flowering than the landraces, which possibly contributed to its higher yield (Table 4): FHIA–21 produced 43% more than the landraces. ■

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The authors work at the Crops Research Institute, PO Box 3785, Kumasi, Ghana.

Socioeconomics | **Survey of banana producers**

Results of a survey on bananas conducted among farmers in the Democratic Republic of Congo

Bakelana-ba-Kufimfutu, Vangu Phaka and Mputu Kena Kudia

Bananas are a staple food for the Congolese and also a very important source of income for the farmers who grow them.

An exploratory survey was performed among banana growers to increase the body of production statistics. It was conducted in the various production zones in the Congo.

The survey was started in the Cataractes District in the Mbanza-Ngungu area and the Bas-Fleuve (Lower Congo) District in the Sehebanza area. Thirty-six farmers were questioned about various aspects of the cultivation and marketing of bananas. The results of the first part of this survey are provided below.

Methodology

An inventory of banana production zones was performed in the Lower Congo region. On the basis of the financial and material resources available, several farmers selected at random were interviewed by the personnel of the INERA M'vuazi Banana Programme. The number of farmers questioned was proportional to the size of the village.

Results

The use of farmers' banana production

Bananas are both a foodstuff and a source of income for most of the farmers questioned. Growers hardly ever use banana in the production of local beverages; these are generally based on pineapple, sugar cane and orange (Table 1). They do not usually know the precise quantity of bananas produced, eaten or sold on the market each year.

Area and ownership of cultivated land

Although the area cultivated by each farmer is not known precisely, the farmers in the Lower Congo district farm larger holdings than those in the Cataractes district (Table 2). This is explained by the on-farm consumption of bananas in each district (Table 1) and also by the more or less favourable nature of the production environment (savannah in the Cataractes district and forest in the Lower Congo). As farmers cultivate with hoes, the areas do not exceed 1 hectare.

Land belongs mainly to the extended family. Some husbands living in their in-laws' villages cultivate the latter's land. Nevertheless, 27% of the farmers rent their land in the Sehebanza area in the Lower Congo district where there are large banana plantations in the forest area (Table 3).

Types of bananas grown

All the farmers questioned grow both sweet bananas and plantains. Cooking and beer bananas are not grown in the districts surveyed. In certain circumstances, some families use sweet bananas as cooking bananas and extremely ripe plantains for the manufacture of local beverages.

Cropping systems

Banana monoculture is more important in the Lower Congo district than in the Cataractes district (Table 4). Home gardens are also more frequent in the Lower Congo district because of the importance of banana as a staple food for the population of this district.

Sucker planting system

Most farmers replant suckers directly in the field after desuckering (81% in the Cataractes district and 93% in the Lower Congo district). Only 19% (Cataractes) and 7% (Lower Congo) of

Table 1. Use of the bananas grown by farmers.

Use	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Consumption	40	70
Manufacture of local beverage	0	0
Source of income	90	100

Table 2. Cultivated area.

Area (ha)	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
≤0.10	57	7
≤0.50	24	63
≤1.00	19	30

Table 3. Ownership of cultivated land.

Owner of the land cultivated	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Extended family	86	60
In-laws	14	10
Other	0	27

Table 4. Cropping systems.

Cropping systems	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Monoculture in savannah	17	10
Monoculture in forest	16	35
Intercropping	50	10
Home gardens	17	20

Table 5. Sources of supply of planting material.

Sources of supply	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Farmer's field	57	67
From a neighbour	17	33
Purchased on the market	26	0

farmers plant them in holes prepared in advance in the field.

Fertilisation of bananas

Bananas must be fertilised with inorganic or organic fertiliser to ensure the satisfactory nutrition of the growing plants.

Most farmers do not fertilise banana. Those who do so use organic wastes (10% in the Cataractes district). The use of inorganic fertiliser is non-existent among smallholders.

Origin of the planting material

Banana was an industrial crop in the Lower Congo district 30 years ago and enormous quantities of 'Gros Michel' fruits were produced and exported to Belgium. The degeneration of the cultivars and the continual destruction of the old plantations made it difficult for farmers to obtain planting material.

A large proportion of planting material is produced naturally by the farmers themselves. Some obtain better quality material from their neighbours through good relations. Purchases of plant material on the market are rare (Table 5).

The storage of banana products

Farmers store their produce in different ways. Most keep their harvest in the village in sheds and in small buildings next to their houses for better supervision and to prevent theft (Table 6).

Diseases

Banana-growing is often affected by various fungal, bacterial and viral diseases and by pest damage. Only the borer called «Nyombé» is identified by most of the farmers questioned. In a general manner, as a result of lack of training, the farmers do not recognise the different diseases. For example, they think that black Sigatoka disease of banana is leaf wilt because the plant is old.

Organisation of work in the field

Who do male or female farmers work with in the field? In more than 40% of cases, the nuclear family (husband, wife and children) participate in fieldwork. Nevertheless, a large number of husbands work alone in the fields while their wives perform other family activities (Table 7).

The uses of banana

Bananas have many uses that vary from one zone to another. All the farmers questioned use sweet bananas as a dessert. Some also eat plantain; it is boiled or prepared as a paste for use as a condiment with other foods (Table 8).

Distribution of production

Bananas are above all a source of income for the farmers questioned. On-farm consumption represents approximately 30% of total production (Table 9).

Marketing of bananas

Very few farmers sell banana bunches in the field. The great majority sell their harvest in the village to middlemen who come from urban centres. Village banana sales are substantial where access to the villages is good, as in the Lower Congo area (Table 10).

Table 6. Storage locations.

Storage location	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
In the farmer's field	20	0
In the village	80	100
At the market	0	0

Table 7. Smallholding labour.

Labour	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Husband alone	43	27
Husband and wife	10	27
Nuclear family	43	47
Extended family	4	9

Table 8. The uses of banana.

Uses of banana	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
Eaten as dessert	100	100
Boiled	86	40
Pounded to paste	14	60
Local beer	0	0

Table 9. Distribution of production.

Distribution of production	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
On-farm consumption	29	35
Source of income	71	65

Table 10. Marketing of bananas.

Sale	Distribution of farmers by district (%)	
	Cataractes	Lower Congo
In the field	0	0
In the village	42	76
At the roadside	4	10
On local markets	30	6
In urban centres	22	0

Few traders go to the villages in the Cataractes district, where the roads serving farms are often in poor condition. Many farmers go to local markets in person to sell their produce (Table 10). ■

The authors work at the *Institut National pour l'Etude et la Recherche Agronomique*, BP 2007, Kinshasa I, Democratic Republic of Congo.

Round table on cooking banana in subtropical zones

An international workshop on cooking banana in subtropical zones was held from 29 November to 3 December 1999 at *Instituto Canario de Investigaciones Agrarias* (ICIA, Tenerife, Spain). It was attended by Ramón Valmayor from the Philippines, Sylvio Belalcázar from Colombia, Thierry Lescot from France (CIRAD-FHLOR) and, for ICIA, Juan Cabrera Cabrera, María José Grajal Martín and Victor Galán Saúco, the coordinator of the meeting. The event was held in the light of the need to study the potential of cooking bananas in the subtropics.

The present importance of cooking banana in various parts of the world (Asia, America and Africa) was described. Discussions covered the most important groups or cultivars in the light of the agronomic characteristics and potential that these types of banana might represent in subtropical zones. It was suggested that it might be advantageous to open an international "work space" co-ordinated by INIBAP to evaluate plant material other than Cavendish for subtropical zones.

The conclusion consisted of the first census of the various cooking bananas and of several banana types other than Cavendish that could be evaluated in subtropical zones. Special attention was paid to the "low habit" parameter of the plants. The list includes the possible origins of cultivars with maximum guarantees that might be entrusted to INIBAP for subsequent study. This could include characterisation and evaluation in subtropical zones. Three of the papers delivered at the meeting are published below.

Preliminary study on the advantages of the cooking banana 'Topocho verde' (ABB) for the Canary Islands

J. Cabrera Cabrera and V. Galán Saúco

The cultivation of cooking bananas in the Canary Islands is limited to a few isolated plants at field edges or gardens. There is no commercial cropping or organised marketing.

The cultivar 'Topocho Verde' (ABB) was tested to perform a preliminary agronomic and commercial exploration. The fruit of the variety is well known and much appreciated by Latin American emigrants who come mainly from Cuba and Venezuela and form substantial population groups not only in the Canary Islands but also in Spain and in Europe as a whole.

In addition, interest in the diversity of food available in the tourist sector—a pillar of the Canary Island economy—could contribute to promoting the establishment of this cultivar or others of the same type.

Design and performance of the experiment

The experiment was performed in two plots in different zones, one in the open air at Guía de Isora in southern Tenerife and the other in glasshouses 9 m high at Gáldar in the north of Gran Canaria island.

The plant material used was from the ICIA germplasm collection and was multiplied *in vitro* by ICIA's Ornamental Plants and Horticulture Department, thus ensuring good sanitary condition. It is thought that the clone is similar to the cultivar 'Bluggoe' or 'Cachaco'.

The main data concerning the start-up of the experiment are shown in the Table below.

Plot	Planting date	Plantation characteristics	Density (plants/ ha)
Open air	26/08/1996	2.5 m x 5.0 m (3 plants per hole)	2400
Green house	17/01/1997	2.0 m x 6.0 m (2 plants per hole)	1666

Local fertigation and a cultural programme in conformity with those generally used for the cultivar 'Grande naine' were applied. The pseudostem was cut back to a height of 1.50 m in the greenhouse in the second cycle to prevent the plants from growing excessively tall.

The most significant data were recorded for the appraisal of both agronomic practices and the productivity of the two types of plantation. The fate of the fruits harvested was also monitored as far as retail sale to consumers in order to study the commercial potential and the degree of acceptance on the local market.

Results and conclusions

The data in Table 1 show the results in the two plots studied and lead to estimating a potential yield of approximately 40 tonnes per hectare.

In the greenhouse, the pruning of the plants in the second production cycle to prevent them from growing too tall resulted in a considerable decrease in harvest quantity. It would therefore be necessary to seek smaller clones, which would also make handling easier and increase the wind resistance of open field plantations.

For this reason and with a view to a future evaluation, a dwarf clone introduced from Venezuela and cultivated in the Canary Islands by a local producer is being multiplied *in vitro*. In parallel, other mutants whose possible small height might be interesting are currently being selected.

In addition, fruits with a more or less intense silvery colour have been noted, although it is not yet possible to confirm that this character will be maintained in subsequent cycles. If this were to be the case, differentiated lines should be bred and the *in vitro* cycle started again to multiply them and verify the stability of this parameter.

The degree of acceptance on the local market is very high as the price paid was over double that of dessert bananas. In addition, the fact that the fruits are sold green with no ripening, unlike dessert bananas, is a definite advantage for the farmer and retailer and should be mentioned here.

Being able to propose a cooking banana that fills a market slot—however

Table 1. Topocho Verde (ABB) cooking banana – Results of trials.

	Pseudostem height (cm) (A)	Pseudostem diameter (cm) (B)	(A)/(B)	Hands per bunch	Harvest date	Bunch weight (kg)	Estimated yield (kg/ha)
Open air 1st cycle	358	60.0	5.95	6.8	07/01/98	18.5	35 899
Open air 2nd cycle	399	65.0	6.17	6.3	03/12/98	21.8	42 294
Greenhouse 1st cycle	517	71.9	7.19	8.0	16/05/98	33.4	45 047
Greenhouse 2nd cycle	499	70.9	7.04	6.3	27/03/99	20.9	28 136

	Upper 2nd hand			Lower 2nd hand		
	Finger length (cm)	Finger width(mm)	No. of fingers	Finger length (cm)	Finger width (mm)	No. of fingers
Open air 1st cycle	20.0	43.0	13	19.0	41.0	12
Open air 2nd cycle	22.0	48.0	12	19.0	45.0	12
Greenhouse 1st cycle	28.2	50.3	nd	24.5	47.5	nd
Greenhouse 2nd cycle	28.4	46.8	nd	25.3	44.0	nd

nd: no data.

tiny—that will doubtless grow should be taken into account by Canary Island growers. The experiment was thus intended to open up a pathway by showing that there is real scope for the profitable cultivation of a banana cultivar that differs from traditional varieties. ■

The authors work at the *Departamento de Fruticultura Tropical, Instituto Canario de Investigaciones Agrarias* (ICIA), Apdo 60, La Laguna, Tenerife, Canary Islands.

The importance of plantains and cooking bananas in Africa: outlets for the subtropical zones

T. Lescot

Banana production in Africa was estimated to total some 29.6 million tonnes in 1998, representing 33.8% of world production.

African production is distributed as follows (Figure 1):

- Plantains (AAB group, "Plantain" subgroup): 10.3 million tonnes (of which about 6000 tonnes is exported annually), forming 34.9% of total African production.
- Other cooking bananas (AAA, ABB and AAB groups, excluding the "Plantain" subgroup): 12.56 million tonnes, forming 42.5% of total African production.
- Dessert bananas (AA, AAA and AAB groups): 6.7 million tonnes (including 467 000 tonnes exported each year), i.e. 22.6% of total African production.

Total in 1998: 29.6 MT = 33.8% of world production

Table 1 provides data on production by types, export estimates for 1998/99 as well as data on *per capita* consumption and planted areas.

Distribution of varieties, utilisation

Although it is true that bananas originated in South-East Asia, Africa has contributed to the diversity of the genus *Musa* by enriching it with two secondary lines of diversification:

- "Plantains" (AAB), in central Africa, with about 100 cultivated varieties or clones.
- East African highland bananas (AAAea), with about 100 cultivated varieties or clones.

Practically all the groups and subgroups of the genus *Musa* ("Eumusa" section) are represented in Africa and are almost all eaten in two forms: fresh and/or cooked (or processed):

AA: Sucrier

AAA: Gros Michel, Red, Ibota, Lujugira/Mutika (AAAea)

AAB: Plantain, Silk, Pome (Prata)

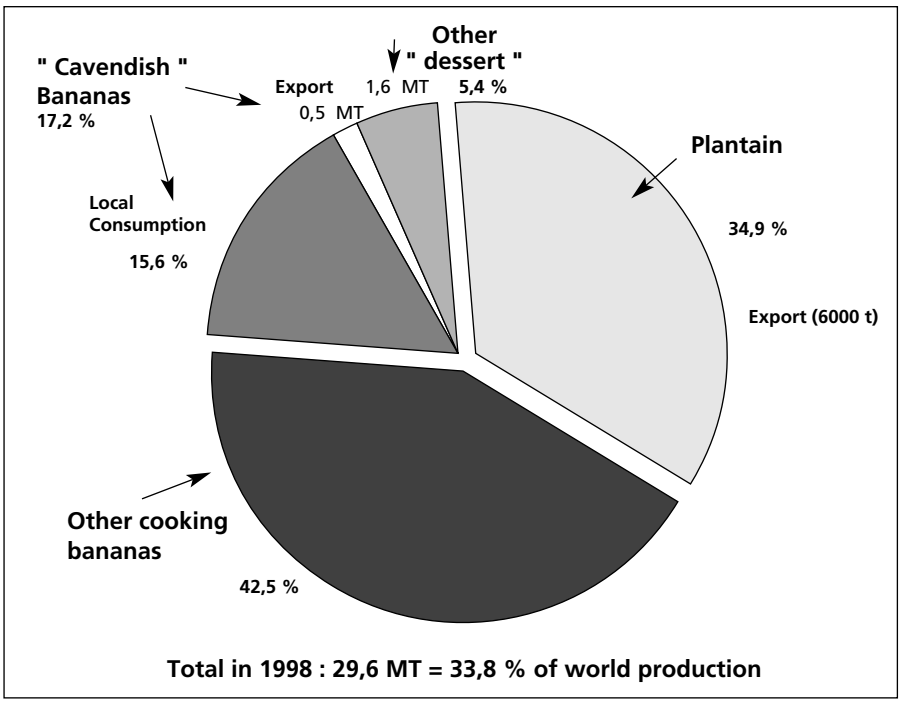

Figure 1. Musa *production in Africa.*

ABB: Bluggoe, Pisang awak, Monthan, Pelipita

The multiplicity of ethnic groups results in great variety in practices in production, consumption, processing and the use of by-products.

Considerable variety is observed in culinary preparations:

- Boiled (green) whole
- Boiled (green) for purée (crushed fruit)
- Fried in oil (ripe/semi-ripe)
- Grilled over embers/in the oven, with or without peel (ripe/semi-ripe)
- Ground/crushed (green) and then dried and mixed with flour and water to form a paste/purée
- AAAea: the (ripe) fruits are set to ferment; the juice is extracted and fermented to make "beer/wine" or distilled to make alcohol
- AAB plantain and ABB cooking bananas: chips and a variety of other products.

There are also many by-products:

- Ash prepared from burned banana peel (high potassium content) is used in soap-making
- Dried, half-burned peel is an additive for tobacco
- Dried sucker fibres (stem) are used to manufacture sponges
- Fresh pseudostem is used as cattle feed
- Pseudostems, petioles and the central vein of dried leaves are used for the manufactures of rope, espadrilles, etc.
- Dried/fresh leaves are used in materials for packing, roofing, etc.

Bananas form an important part of the diet and are much appreciated as

Table 1. Bananas and plantains in Africa: production, export, consumption and planted areas (source: T. Lescot 1999, FruiTrop 63).

Production of bananas and plantains (tonnes)						Estimate 98/99					
	Plantains AAB	Highland bananas ABB + other cooking bananas	Cavendish bananas	Gros Michel + other dessert bananas	TOTAL	Export		Consumption (kg/capita)		Area (ha)	
						Cavendish	Plantains	Bananas	Plantains	Plantain	Commercial bananas
Afrique occidentale et centrale											
Angola	140000	10000	275000	10000	**435000**			23,47	11,95	23333	
Benin	3000	100	13000	14950	**31050**			2,31	0,53	207	
Cameroon	1030000	30000	456000	500000	**2016000**	220000	5000	16,95	73,61	200000	5700
Cape Verde	1	1	8000	1	**8003**	1000		17,54	0,00		160
Congo	66000	10000	31000	6000	**113000**			11,44	24,36	11000	
Côte d'Ivoire	1200000	10000	390000	10000	**1610000**	199700	128	13,53	85,32	200000	5620
Gabon	120000	30000	11000	10000	**171000**			9,67	105,54	20000	
Ghana	1798000	60000	19000	500	**1877500**	3400	500	0,84	96,35	299667	
Guinea	419000	10000	130000	10000	**569000**			17,75	57,20	69833	
Guinea Bissau	34500	1000	4000	500	**40000**			3,52	30,37	5750	
Equatorial Guinea	8000	1000	7000	1000	**17000**			16,67	19,05	1333	
Mali		10	10200	10	**10220**			0,98	0,00		
Liberia	35000	5000	58000	22000	**120000**			24,15	14,57	5833	
Nigeria	1675000	12000	10000	20000	**1717000**		1	0,10	16,12	279167	
Sao Tome & Principe	6500	1500	4200	3800	**16000**		2	30,43	47,09	1083	
Senegal	100	10	7500	900	**8510**			0,85	0,01	17	800
Sierra Leone	26000	500	1000	500	**28000**			0,23	5,88	4333	
Togo	1000	500	14100	500	**16100**	15	72	3,29	0,22	167	
Central African Rep.	70000	10000	60000	40000	**180000**			17,54	20,47	11667	
Zaire (CDR)	2250000	462400	339600	80000	**3132000**		1	7,08	46,89	380000	
TOTAL	**8882101**	**654021**	**1848600**	**730661**	**12115383**	**424115**	**5704**	**5.42**	**33.77**	**1513390**	**12280**
%	73.31	5.40	15.26	6.03	%	3.50	0.05				
Eastern Africa											
South Africa			199500	500	**200000**	464		5,14	0,00		
Burundi	70000	1100000	80000	274500	**1524500**		74	12,57	10,99	11667	
Comoros	10000	10000	27000	10000	**57000**			42,19	15,63	1667	
Ethiopia			81000		**81000**			1,39	0,00		
Kenya	390000	135000	120000	10000	**655000**	66	3	4,22	13,71	65000	
Madagascar	1000	5000	229000	30000	**265000**	5900		15,26	0,07	167	
Malawi	202000	5000	84000	2000	**293000**			8,34	20,07	33667	
Maurice	1	5	9000	10	**9016**			7,94	0,00		
Mozambique	1000	1000	84000	1000	**87000**			4,55	0,05	167	
Uganda	310000	9000000	425000	100000	**9835000**	2557	200	21,12	15,49	51667	
Reunion Island	1	5	10000	10	**10016**			14,86	0,00		
Rwanda	100000	1568000	145000	435000	**2248000**		7	24,32	16,77	16667	
Seychelles	100	500	1100	250	**1950**			14,67	1,33	17	
Somalia	2000	10	51000	20	**53030**	25000		2,95	0,23	333	1000
Sudan			70500		**70500**			2,54	0,00		
Swaziland			500		**500**			0,54	0,00		
Tanzania	350000	80000	345000	2912	**777912**			10,98	11,14	58333	
Zambia			600		**600**			0,07	0,00		
Zimbabwe			80000		80000	2012		6,95	0,00		
TOTAL	**1436102**	**11904520**	**2042200**	**866202**	**16249024**	**35999**	**284**	**6.87**	**4.92**	**239350**	**1000**
%	8.84	73.26	12.57	5.33	%	0.22	0.00				

Table 1. *continued*

Production of bananas and plantains (tonnes)					Estimate 98/99					
	Plantains AAB	Highland bananas ABB + other cooking bananas	Cavendish bananas	Gros Michel + other dessert bananas	TOTAL	Export		Consumption (kg/capita)		Area (ha)
						Cavendish	Plantains	Bananas	Plantains	Plantain / Commercial bananas
North Africa/Middle East										
Bahrain			800		**800**			1,37	0,00	
Cisjordan			7900		**7900**			24,69	0,00	
Egypt	10	1000	635115		**636125**	11	1	9,81	0,00	14000
United Arab Emirates			150		**150**			0,07	0,00	
Gaza strip			7000		**7000**	5000		2,01	0,00	
Iran			8000		**8000**			0,12	0,00	
Israel			111900		**111900**	777		18,96	0,00	
Jordan			72504		**72504**	14		16,03	0,00	1700
Lebanon	10		110000		**110010**		1	35,00	0,00	
Morocco			102000		**102000**			3,79	0,00	2960
Oman			28000		**28000**	647		11,87	0,00	1114
Syria			160		**160**			0,01	0,00	
Tunisia			55		**55**	1		0,01	0,00	
Turkey			37000		**37000**	360		0,58	0,00	
Yémen			85110		**85110**			5,22	0,00	
TOTAL	**20**	**1000**	**1205694**	**0**	**1206714**	**6810**	**2**	**4,28**	**0,00**	**0 19774**
%	0.00	0.08	99.92	0.00	%	0.56	0.00			
TOTAL AFRICA	**10318223**	**12559541**	**5096494**	**1596863**	**29571121**	**466924**	**5990**	**8,34**	**18,58**	**1752740 33054**
%	34.89	42.47	17.23	5.40	%	1.58	0.02			

a source of energy (carbohydrate). With an average of 10 tonnes per ha per year, production totals approximately 12 million kilocalories per ha per year. Assuming an average production cost of $US 1000 per ha, one dollar produces 6000 kilocalories.

Farming systems

Cropping and farming systems are very varied and display various aspects:

- Production strategies vary considerably: means of subsistence, on-farm consumption, clearing of tropical forest, intercropping with other cash crops (coffee, cocoa, etc.) and/or other food crops, intensive cropping (market), production for export etc. at various densities.
- Bananas are a cheap, steady foodstuff. Production costs are very low and bunches can be harvested weekly.
- Bananas are also a steady source of income, with cultivation all the year round and bunches produced every week.
- Banana is a sustainable crop, with fairly well-balanced carbon cycle and nitrogen.
- Yields are variable but usually low at 4 to 30 tonnes per ha.

Table 2. Susceptibility of bananas to pests and diseases.

Group/clone	YS	BS	*Foc*	Borer	Nematodes
AA					
Sucrier	***	*		*	***
AAA					
Gros Michel (1)	***	***	***	*	**
Red	**	***		*	**
Ibota (Yangambi Km5)					
Lujugira/Mutika (AAAea)	***	***	**	***	***
AAB					
Plátano	*	**		***	***
Silk	***	***	***	**	***
Pome (Prata)	***	***		**	***
ABB					
Bluggoe (2)		*	***	*	**
Pisang awak		*		*	*
Monthan		*		*	*
Pelipita		*		*	*

YS: Yellow Sigatoka; BS: Black Sigatoka; *Foc*: *Fusarium oxysporum* f. sp. *cubense;* *: resistant; **: partially resistant; ***: susceptible; (1) A Cuban clone of 'Gros Michel' is resistant to *Foc* (1-2); (2) A Cuban 'Bluggoe' type clone is resistant to *Foc* (2): "Burro CEMSA 3/4".

Capacity for adaptation in tropical zones

- Small fresh bananas (AA, AAA, AAB): adaptation capacity is generally small to medium, with the exception of 'Silk' AAB (grown in Australia and South Africa) and certain Asian diploids (AA) whose adaptation remains to be demonstrated.
- "Plantains" (AAB): adaptation capacity only in the 'French' subgroup clones from highland areas, with the exception of certain members of the 'False horn' group.
- Highland bananas (AAAea): information is lacking but adaptation capacity should exist.
- Other 'cooking' bananas (ABB): adaptation capacity small to medium.

Susceptibility to pests and diseases

Levels of susceptibility of the various banana types to yellow and black Sigatokas, Fusarium wilt and nematodes are presented in Table 2.

Marketing potential

Even if the export of non Cavendish bananas is presently limited to tourist or ethnic "niche" markets, there is no doubt that the European market half-opens to these other bananas (Table 3, Loeillet 1999).

Conclusion

Fairly great diversity of *Musa* is observed in Africa (the second centre of

Table 3. Market potential of non Cavendish bananas in European Union.

Group/clone	European imports (tonnes)	Trend	Origin	Price*** €/kg
AA				
Sucrier*	18 000	↗	Latin Am./Africa	2.3-5.7
AAA				
Gros Michel*, **	30 000	↗	Latin Am./Africa	?
Red	4 000	↗	Latin Am./Africa	1.2-3.7
Ibota (Yangambi Km5)	-			
Lujugira/Mutika (AAAea)	-			
AAB				
Plátano*	24 000	↗	Latin Am./Africa	0.55-1.4
Silk*	2 000	→	Latin America	2-5
Pome (Prata)	-			
ABB				
Bluggoe	-			
Pisang awak	-			
Monthan	-			
Pelipita	-			

* with 'organic' potential

** processed: purée

*** wholesale price.

diversity after South-East Asia, the zone of origin), especially in the following subgroups: plantain (AAB) and East African bananas (AAA). Various clones can develop normally under subtropical climatic conditions, with a preliminary first stage of behaviour tests, with regard to both agronomy and the post-harvest/ripening period. In the Canaries, development of the production of these varieties depends on the realities of the potential market, which cannot be very great. Indeed, these are 'niche' markets responding to tourist or ethnic demand (local consumption, Spain and Europe). ■

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The author works at CIRAD-FLHOR, BP 5035, 34000 Montpellier cedex 1, France.

Cooking bananas – Classification, production and utilization in South-East Asia

R. V. Valmayor

Bananas are considered to be one of the earliest fruits cultivated by man. The oldest reference to banana appears in the Ramayana, a Sanskrit epic written centuries ago. The magnificent Buddhist temple, Borobudur, constructed in central Java, Indonesia, in 850 BC show stone carvings of banana being offered to the Lord Buddha. The victorious armies of Alexander the Great described the cultivation of banana in the lower Hindus Valley of India in 327 BC. South China is another area where banana cultivation dates back to ancient times. Scriptures written during the reign of Han dynasty (206 BC - 220 AD) mentioned the cultivation of banana more than 2,000 years ago. Because of its antiquity, its long history of domestication in India and China and the great diversity of dessert and culinary cultivars present in these two countries, some writers believed that bananas originated in India or China. However, results of banana exploration missions in Asia during the middle part of this century and the subsequent unveiling of the great wealth of *Musa* germplasm resources collected showed that it is more likely that bananas actually originated in Southeast Asia.

Banana classification in Southeast Asia

Banana classification and nomenclature have been a complicated issue from the very beginning. The problem started with the simplistic description of plantain, *Musa paradisiaca* Linn. and dessert banana, *Musa sapientum* Linn. by Karl Linnaeus, the father of modern botanical nomenclature. The complication emanated from the very limited specimens available to Linnaeus in Europe where the original names were given. While the differentiation between plantains, a special type of cooking banana and dessert bananas is readily applicable in Africa and Latin America, their adoption in Southeast Asia has led to confusion. This is because in the center of *Musa* diversity, many local cultivars possess characteristics that transcend the diagnostic characters used elsewhere to differentiate bananas and plantains

In the center of diversity for bananas, many cultivars are classified as dual purpose, the fruits are consumed either fresh or cooked. There are also many starchy, cooking cultivars with short, stout and angular fruits with dehiscent male flowers and bracts. These cooking bananas are distinct from the plantains and cannot be classified under *Musa paradisiaca*. Furthermore, the great diversity of dessert bananas in terms of plant stature, fruit size and colour (yellow, green, red, and orange) far exceed the rather limited description of the original *Musa sapientum*. To cope with the wealth in germplasm diversity in its center of origin, subsequent banana taxonomists applied such descriptive names as *Musa nana* Lour. for the Dwarf Cavendish, *Musa rubra* Firming. von Wall. for the Red banana, *Musa corniculata* Lour. for the Horn plantain, and many others. The proliferation of scientific names added more confusion to banana nomenclature and the situation would have worsened if it were not for Cheesman (1948) and Simmonds and Shepherd (1955) who explained the origin of edible bananas and proposed a new classification scheme.

Drawing upon their expertise in genetics and vast experience in cytotaxonomy, Simmonds and Shepherd concluded that the Linnean scientific names *Musa paradisiaca* and *Musa sapientum* were based on hybrid cultivars and recommended their abolition. They likewise concluded that the edible bananas originated from two wild and seedy species, *Musa acuminata* Colla and *Musa balbisiana* Colla which are endemic to Southeast Asia. Cheesman recognized three groups of morphologically distinct cultivars. The first group shows predominantly the botanical characters of *Musa acuminata* while the second group of cultivars primarily ex-

hibits the morphological features of *Musa balbisiana*. The third group possesses characteristics that blend the morphological characters of the two wild species and are considered as their natural hybrids. The primitive edible bananas were diploids that evolved through the development of sterility and parthenocarpy in *Musa acuminata*. Through human selection, various clones were brought under cultivation particularly in the rainy parts of Southeast Asia. Later, through chromosome restitution, seedless triploid cultivars developed. Since triploids proved to be more vigorous and productive, they gained greater popularity. Cheesman argued that the seedless, edible diploid cultivars of *Musa acuminata* must be treated in the same species as their wild parents as they retained the morphological characteristics of their wild ancestors. Likewise, the seedless and edible triploid cultivars that developed through chromosome restitution must also be recognized as the same species as their parents because the addition of one set of chromosomes through autopolyploidy did not introduce anything new to the genetic constitution of the clone. In the drier areas of Southeast Asia where the wild and seedy *Musa balbisiana* predominate, a parallel evolutionary development occurred which led to the appearance of pure diploid and triploid *balbisiana* cultivars (Valmayor *et al.* 1991). Since the development of sterility and parthenocarpy did not significantly alter the morphological characteristics of the resultant clones, the scientific name *Musa balbisiana* should also be applied to the edible diploid and triploid cultivars derived from the wild *balbisiana* parents. In the center of origin of bananas, the natural distribution of wild *Musa acuminata* and *Musa balbisiana* overlap and since the two species are cross compatible, hybridization occurred. The hybrids that evolved from the two natural species include diploids, triploids and a few tetraploids in various genome combinations. A major concern about the original terms *Musa paradisiaca* and *Musa sapientum* is their hybrid nature. But according to ICNCP rules (International Code of Nomenclature for Cultivated Plants) hybrids can also be given a scientific name. However, the epithet must carry the prefix **x** to indicate the hybrid nature of the species. In the case of hybrid banana cultivars, *Musa* **x** *paradisiaca* Linn. should be adopted as this binomial was published ahead of *Musa sapientum* and is in fact recognized as the type species for the banana. *Musa* **x** *paradisiaca* Linn. is applicable to all hybrids of *Musa acuminata* and *Musa balbisiana* notwithstanding their genome composition (Greuter 1994, Karamura 1998).

The genome composition of banana cultivars helps in differentiating dessert from cooking varieties. All pure *Musa balbisiana* clones are cooking bananas while many of the pure *Musa acuminata* varieties are dessert bananas. Among the hybrids are dual purpose cultivars (consumed either fresh or cooked), dessert and cooking bananas, including the plantains. The general term plantain is applicable only to a specific subgroup of cooking bananas and do not include the numerous and divergent cooking cultivars that are very popular in Asia. On the other hand, the term banana is not limited to the dessert varieties but also cover all the cooking bananas, including the plantains. In other words, all plantains are also bananas but not all bananas are plantains! This is the reason why in Southeast Asian languages, there is no differentiation between the foreign terms banana and plantain. The common name **pisang** in Malaysia and Indonesia, **saging** in Philippines, **kluai** in Thailand, **choui** in Vietnam and **chiao** in China are applicable to all dessert and cooking bananas, including plantain.

Important banana cultivars in Southeast Asia

The center of origin for bananas is also its center of diversity. In Southeast Asia, the consumers have a wide selection of dessert and cooking cultivars. Banana varieties vary in colour, size, shape and utility. The important commercial cultivars in Southeast Asia are presented in Table 1.

Banana production systems

Banana production in Southeast Asia has been classified into four systems. The most common is backyard production and the farmers grow bananas primarily for home consumption. The choice of cultivars grown depends on family requirements whether dessert or cooking bananas, quality preferences of household members and ease of production. In the backyard production system, labour is entirely supplied by family members. No commercial fertilizers nor pesticides are used, only compost and animal manure are applied.

The second most popular is the mixed-crop production system. In Southeast Asia, the fruit industry is primarily a smallholder enterprise and bananas are grown with other crop commodities. In the mixed-crop production system, bananas can be the primary crop or only a secondary crop, the permanent crop or a temporary crop. A common practice in Southeast Asia is to plant banana as nurse crop to shade-loving plants such as cacao, coffee, black pepper, nutmeg, etc. But in some cases, banana is the crop grown under the shade of taller plants as in coconut plantations. In Malaysia and southern Philippines where plantation crops are extensively grown, banana is often planted as a temporary intercrop to the young rubber and oil palms. The bananas provide income during the non-productive stage of the permanent crop. Once the primary crop becomes established and the bananas interfere with the rubber or oil palms, the bananas are eliminated. In some parts of the Philippines, coconuts, bananas, papayas and pineapple are grown in the same area under a multi-storey combination. A banana-based cropping system highly recommended in Southeast Asia is to plant short duration crops between the rows of newly planted banana.

An emerging popular production system is the commercial small-holder plantation where bananas are grown as a monocrop in areas ranging from 2 to 20 ha. This production system is proliferating near population centers where market demand is strong and steady. The selection of cultivars to grow is dictated by consumersÕ preferences, prevailing agroclimatic conditions and pest and disease situation. In the commercial smallholder plantations, the farmers apply commercial fertilizers and pesticides. They also hire labour to control weeds and in some locations to irrigate the farm.

Large commercial banana plantations that grow fruit for the export markets are also found in Southeast Asia, specifically in the Philippines. These modern corporate-farms cater to the exacting requirements of the banana export trade. Corporate farms are capital intensive and involve heavy investments in plantation infrastructure. Production practices are applied at optimum levels and productivity is very high. Quality of the produce is of primary consideration.

Banana production under adverse environments

The most serious climatic problem that confronts commercial producers of banana in Asia and the Pacific are the tropical storms and typhoons. Bananas are sensitive to strong winds, especially for tall cultivars bearing a

heavy bunch of fruit. Storms at 54 to 72 kph cause serious blowdowns and typhoons at more than 72 kph can result in complete destruction of banana plantations. Taiwan, South China, Vietnam, northern and central Philippines and many island countries in the South Pacific are annually subjected to this calamity. But the occurrence of typhoons is seasonal and it coincides with the monsoon months. After consistently suffering heavy losses caused by tropical storms and typhoons that occur with predictable regularity, the banana growers in Taiwan and the Ilocos region in northern Philippines have adapted a planting calendar with corresponding plantation management practices that ensures minimal damage caused by strong winds (Valmayor *et al.* 1998). In the case of northern Philippines, the tropical cyclones begin in June and cease in November with highest frequency during the months of July, August and September. To avoid damage caused by wind storms, planting is scheduled in May so that the bananas are still small and damage is minimal when the typhoons pass over the region. The monsoon rains decline in November and so with the typhoon season only to reappear in June the following year. With irrigation, plant growth and development continue and flowering takes place in late February or early March and the fruit bunches mature in April or May, one year after planting. Harvesting is completed before the onset of next year's stormy weather. The resultant effect of the strict adherence to this cropping system is the annual cropping of bananas. After harvest time, supply becomes very scarce but banana farmers avoid heavy losses due to typhoons. It is important that only cultivars that mature in 12 months or less are selected for this cropping system. All suckers that sprout from July to January should be removed as allowing them to develop will only subject them to wind damage the following typhoon season. The suckers that develop after flowering will be allowed to grow, but only one, the most vigorous will be nurtured to replace the mother plant and start a second cropping cycle. To compensate for harvesting only one fruit bunch per mat per 12 months cycle, a closer distance of planting at 2x2 meters is recommended.

In Thailand, flooding is a serious problem on the flood plains around Bangkok, particularly during the rainy season. To overcome the problem of high water table and poor drainage, the farmers grow bananas on beds or ridges constructed between drainage canals. The beds measure 2 to 3 meters wide and several meters long and are built-up by depositing the soil dug from canals alongside the raised beds. Rows of bananas are planted once the beds are 1 meter above the canal water level. Vietnamese farmers in the Mekong River delta, particularly those close to Saigon also grow bananas on raised beds. The more progressive growers in both countries drain the excess water through volume pumps during the monsoon season and draw water from the canals to irrigate their bananas during the dry season.

Other natural calamities confronting banana growers in Southeast Asia are droughts and volcanic eruptions. In eastern Indonesia, the western parts of Luzon and the Visayas in the Philippines where the dry season is long extended, the drought tolerant varieties of pure *balbisiana* genome composition (BBB) such as Pisang Kepok, Saba and Cardaba are planted while in the dry areas of Thailand and Malaysia, a hybrid with ABB genome constitution locally known as Kluai Namwa or Pisang Awak is the favorite cultivar. The banana farmers in the region are helpless against volcanic eruptions but fortunately, occurrence is rare and the area affected is generally not as extensive as calamities caused by typhoons and droughts.

Table 1. Important commercial cultivars of banana in Southeast Asia.

Country	Dessert varieties	Cooking varieties
Indonesia	Pisang Ambon Putih	Pisang Kepok
	Pisang Ambon Lumut	Pisang Oli
	Pisang Raja Sereh	Pisang Kosta
	Pisang Raja**	Pisang Tanduk*
	Pisang Barangan	Pisang Nangka*
	Pisang Mas	
Malaysia	Pisang Masá	Pisang Awak
	Pisang Rastali	Pisang Raja**
	Pisang Embun	Pisang Nangka*
	Pisang Berangan	Pisang Tandok*
	Pisang Masak Hijau	Pisang Nipah
	Pisang Lemak Manis	
Thailand	Kluai Hom Thongá	Kluai Namwa**
	Kluai Khai	Kluai Hakmuk
	Kluai Lep Mu Nang	Kluai Som
Vietnam	Chuoi Tien	Chuoi Mat
	Chuoi Tieu	Chuoi Sap
	Chuoi Tay	Chuoi Ngu
	Chuoi Bom	
Philippines	Lakatan	Saba
	Latundan	Sabang Puti
	Buñgulan	Cardaba
	Inarnibal	Turangkog
	Amas	Matavia
	Morado	Tindok*
	Giant Cavendishá	Laknau*
	Grande Naine***	

* Plantain, **Eaten fresh or cooked, ***Export variety.

Processing and utilization of banana

Bananas are primarily traded in fresh form and consumed as such. However, cooking bananas and plantains make excellent chips, a popular snack item in Southeast Asian countries. The Philippines is the biggest world exporter of banana chips amounting to some US$22 million per year. Thailand and Indonesia have also developed export markets for banana chips. Other major processed products derived from banana are banana catsup and bottled baby food. ■

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The author is Honorary Research Fellow, INIBAP.

Which banana variety should I grow?

Jeff Daniells

In Australia and elsewhere, there is a growing interest in alternative banana varieties. This is largely driven by:

1) Emergence of new diseases/new strains of exotic diseases
2) Desire to reduce pesticide usage
3) Development of niche markets.

The Queensland Department of Primary Industries in Australia has evaluated the agronomic and disease resistance characteristics of hundreds of varieties over the past 15 years. It has become fairly clear from these studies that there is no 'perfect' variety – one that is resistant to all pests and diseases, yields high, is good to eat and handles well. Each variety has its own advantages and disadvantages. This article attempts to provide useful information about the better varieties identified by QDPI. Readers should however bear in mind that the solution to their production problems may not just lie with improved genotypes. Holistic integrated crop management approaches also have much to offer (Daniells 1998).

Checklist

Table 1 is a checklist of the better varieties with their relative positive and negative characteristics listed. It should be noted that varietal responses can vary according to the environment they are grown in, and the strains of diseases they are exposed to. Whether a variety is suitable for dessert or cooking purposes is governed largely by cultural preferences. Varieties suitable for evaluation for particular circumstances can be deduced from the checklist.

Additional Notes

Yield

Most variety alternatives to Cavendish are lower yielding than Cavendish. Therefore, if they are grown for local or export markets, they must command better prices and/or be cheaper to produce than Cavendish. Some varieties, e.g. Sucrier, are very quick cycling, but this still does not make up much for their lower bunch weights.

Wind susceptibility

As a general rule, dwarf varieties are more resistant to wind damage and are also easier to support with props or twine. Dwarf varieties are also easier to manage for leaf disease, bunch pests, bunch trimming, bunch covering and harvesting. Unfortunately dwarf varieties tend to be more prone to 'choke throat' and they are sometimes associated with smaller fruit. Further strategies to minimise losses from wind are detailed by Daniells (1991b).

Purpose

Virtually all varieties of bananas and plantains may be either eaten raw when ripe (dessert) or cooked when either green or ripe. Cultural preferences govern the choices made. Many 'new' varieties have still to be evaluated for a wide range of potential purposes.

The dwarf stature of Dwarf French Plantain facilitates management.

Sigatokas

The severity of disease depends upon the resistance or susceptibility of the variety, the intensity of infection, environmental conditions and the 'strain' of the pathogen present. Disease incidence will be greatest under hot wet conditions with high inoculum levels. TU8 (T8) was originally highly resistant to black Sigatoka in the Cook Islands (Fullerton 1990) but new strains of the disease have since rendered this

Table 1. Variety plant characteristics and disease resistance checklists.

Genome	Variety	Synonyms/*Subgroup*	Plant characteristics					Disease resistance					
			Purpose	Yield	Wind susceptibility	Stature	Comments	BS	YS	Fusarium wilt[1]			Comments
										Race 1 [2]	Race 2	Race 4	
AA	Sucrier	Pisang Mas Kluai Khai Amas Figue Sucrée	D	L	PR	I		S [3]	S	R	R	S	
	Inarnibal Pisang Berlin	Pisang Lemak Manis	D	L	PR	n		R	S	R	R	S	
	Lakatan [4]	Pisang Berangan	D	L-M	S	I	Long green life	VS	VS	R	R	S	
AAA	Dwarf Red	Figue Rose Naine	D	M	R [5]	n	Some choke throat problems	S	S	S	R	S	
	J.D. Yangambi	Pisang Kapas? *Ibota*	D/C	M	PR	I		HR	HR	R	R	S	R to burrowing nematode and banana weevil borer
	Kluai Khai Bonng		D	L-M	VS	I	Very active fruit	R?	HR	R	R	S	R to banana weevil borer
	Williams	*Cavendish*	D	H	S	dw	Long green life	VS	VS	R	R	S	

Table 1. *continued*

Genome	Variety	Synonyms/ *Sub group*	Plant characteristics					Disease resistance					
			Purpose	Yield	Wind susceptibility	Stature	Comments	BS	YS	Fusarium wilt[1]			Comments
										Race 1 [2]	Race 2	Race 4	
AAAA	T6	61-86 *Highgate hybrid*	D	M-H	S	I		R	HR	R	R	S	
	T12	Buccaneer, 65-168-12, *Highgate hybrid*	D	M-H	S	I		R	R	R	S		
	SH-3436	*Highgate hybrid*	D	H	S	I		R	S	R	R	S	
	SH-3444	FHIA-23, *Highgate hybrid*	D	H	S	I		R	S	R	R	S	
	SH-3649	FHIA-17, *Highgate hybrid*	D	H	S	I		R	S	R	R	S	
	SH-3486	FHIA-02, Mona Lisa *Williams hybrid*?	D	M-H	PR	I		HR	S?	S	R	S	
AAAB	SH-3480	FHIA-18, *Pome hybrid*	D	M-H	PR	I		HR	R?	R	R	R	
	SH-3481	FHIA-01 Goldfinger, *Pome hybrid*	D	M-H	PR	I		HR	S	R	R	R[6]	R to burrowing nematode
	SH-3640.10	High Noon, *Pome hybrid*	D	M-H	PR	I		HR	VS	R	R	R	
	SH-3697	*Maqueño hybrid*	C	M-H	S?	T		R	R?	S	R	S	
	PC 12.05	*Pome hybrid*	D	L-M	PR	T		S	R	R	R	S	
	PA 03.22	*Pome hybrid*	D	L-M	R	I		S	R	R	R	S	
AAB	Silk	Apple, Pisang Raja Sereh, Pisang Rastali, Latundan, Sugar, Figue Pomme, Manzano	D	L-M	PR	I		S	S	S	S	S	
Pisang Ceylan		*Mysore*[7]		D	M	S	T		R	R	S[8]	R	S[8]
	Pisang Raja		D/C	L-M	S	T		S	S	R	R	S	
	Prata Anã	Santa Catarina Prata, *Pome*	D	L-M	VR	I	Short green life[9], some choke throat problems	VS	S	S	R	S	
	J. D. Finger	Rajapuri?, *Pome*	D	L-M	VR	dw	some choke throat problems	VS	S	S	R	S	
	Lady Finger	*Pome*	D	L-M	R	I		VS	S	S	R	S	
	Pacific Plantain	*Maia Maoli/Popoulu*	C	M	R	I	Long green life	S	S	S	R	S	
	Mangaro Torotea	*Maia Maoli/Popoulu*	C	M	PR	T		S	S	S	R	S	
	Dwarf French Plantain	*Plantain*	C	L-M	R[5]	dw		S	R	R	R	S	VS to banana weevil borer
	Horn Plantain	Tanduk, Pisang Tandok, *Plantain*	C	L-M	S	I		S	R[10]	R	R	S	VS to banana weevil borer
ABB	Kluai Namwa Khom	*Pisang Awak*	D/C	M	R[5]	dw	Some dummy finger[11] problems Short green life	HR	HR	S	R	S	
	Pisang Awak	Ducasse, Kluai Namwa	D/C	M	PR	T	Short green life	HR	HR	S	R	S	
	Bluggoe		C	L-M	PR	I		R	HR	R	S	S	
	Blue Java	Ney Mannan	D/C	L-M	PR	I		R	HR	R	S	S	
	Fa'i Afa	*Saba*	C	L-M	PR	T		R	HR	S	R	S	
	Gubao	IMTP Phase 2 'Saba'	C	M	S	I		R	HR	S	R	S	
	Kandrian	Simoi	C	L-M	PR	T		R	HR	R?	R	S	
AABB	SH-3565	FHIA-03	C	M-H	S	I		R	S?	S	R	S	

Abbreviations used:

Purpose: D = dessert; C = cooking

Yield: L = low; M = moderate; H = high

Wind susceptibility: VS = very susceptible; S = susceptible; PR = partially resistant; R = resistant

Stature: dw = dwarf; I = intermediate; T = tall

Disease resistance and related comments: BS = black Sigatoka; YS = yellow Sigatoka; VS = very susceptible; S = susceptible; R = resistant; HR = highly resistant.

Notes

(1) New races can develop/= usual reaction

(2) VCG groups vary particularly Race 1 types vs. varietal pathogenicity

(3) IMTP 1 was borderline on susceptible – resistant but Sucrier has certainly been resistant under some circumstances (Jones 1993)

(4) There are reports that some Lakatan may be AAA

(5) Benefits from bunch support

(6) Reported by INIBAP as tolerant but questionable

(7) Superficially the same

(8) Sometimes ratoon resistance

(9) Short green-life during environmental stress e.g. cool temperatures/wet season

(10) Susceptible under some circumstances (Daniells and Bryde 1999)

(11) Some fingers do not properly fill out.

variety susceptible in that environment.

Black Sigatoka is present in many producing countries but some major production areas, such as parts of Brazil, Australia, parts of SE Asia and high altitude tropical areas such as in Cameroon are still free of this disease. In those areas yellow Sigatoka remains the most important leaf disease.

Fusarium (*Foc*)

The different races of Fusarium shown in the checklist are based on the host–pathogen interaction. Although during the last decade, isolates of *Foc* have been genetically characterised in several different ways, race is still used by many to distinguish pathogenic variation in the fungus. Traditionally, four races of *Foc* are recognised. Races 1, 2 and 4 affect bananas, while Race 3 affects *Heliconia* and is only weakly pathogenic in banana. It

should be noted that, to date, there are very few varieties known to be resistant to *Foc* Race 4. Quarantine is extremely important for stopping further spread of this pathogen.

Various races of Fusarium wilt are present in most banana-producing regions of the world but the disease is noticeably absent from the South Pacific. Hybrids from breeding programmes, which may be rejected because of susceptibility to Fusarium wilt, could in fact be very useful in places such as the South Pacific where resistance to Fusarium wilt is currently unimportant. An example of this is SH-3697 – a high yielding Maqueño hybrid resistant to black Sigatoka but susceptible to *Foc* Race 1.

It should be noted that there are gradations of resistance to Fusarium. For example Lady Finger (AAB, Pome) is much less susceptible to *Foc* Race 1 than Sugar (AAB, Silk) in the north Queensland environment. Environmental conditions can also influence the severity of the disease reaction.

Finger drop

Some varieties are very prone to finger drop during ripening, and this has restricted the adoption of new hybrids in some areas in the past (Marriott 1980). However, the susceptibility of varieties to finger drop can be minimised by varying the ripening conditions, including the use of lower temperatures, and the stage of maturity at which fruit is harvested (Paull 1996, Seberry and Harris 1998).

Fruit greenlife

Sufficient transport/storage life of fruit is particularly important for export situations. One of the great virtues of Cavendish-type bananas is their long greenlife when properly managed. Some other varieties are not so well suited for export marketing. However, techniques such as modified atmosphere packaging and good management can help overcome such problems (Daniells 1991a).

J.D. Finger is very resistant to wind damage.

Lakatan is the most popular dessert variety of the Philippines.

Niche markets

The following varieties have been identified as having potential for niche markets in Australia as well as for export:

- Sucrier
- SH-3697
- Dwarf French Plantain
- Lakatan
- Silk
- Horn Plantain
- Dwarf Red
- Pisang Ceylan
- Kluai Namwa Khom
- Kluai Khai Bonng
- Prata Anã
- Pisang Awak
- SH-3480 (FHIA-18)
- Pacific Plantain
- Fa'i Afa ■

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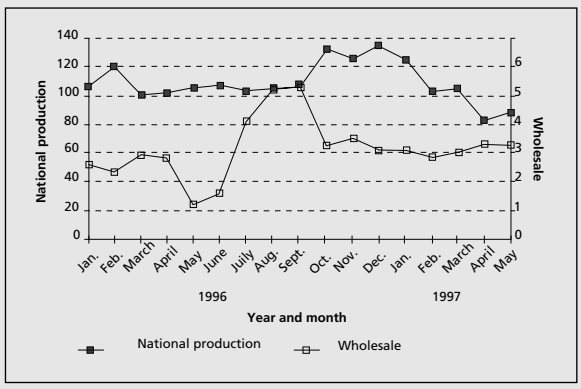
The author works at The Queensland Department of Primary Industries (QDPI), PO Box 20, South Johnstone Q 4859, Australia.

Errata in previous issue (Info*Musa* Vol. 8, No. 2)

- **Evaluation of bananas for niche markets in subtropical Florida**: p. 17, at the bottom of Table 1, **Fe'i banana Rimina** should appear in boldface and be separated from the above section (AABB genome) to which it does not belong; and p. 18, at the end of first column/top of second column, the passage "…differences between two clones of 'Ney poovan', one of which, 'Sukali ndizi', develops symptoms more slowly than the other, 'Kisubi'..." should read "…differences between two clones of 'Ney poovan', one of which, 'Kisubi', develops symptoms more slowly than the other, 'Sukali ndizi'…".
- ***Musa* clones in Peru: classification, uses, production potential and constraints:** p. 22, Figure 3, the scale of the right y-axis has been omitted. The correct version of the figure is given at right.



Asia and the Pacific

The Food and Fertilizer Technology Centre in Taiwan publishes an Extension Bulletin on the production of virus-free banana plantlets in Taiwan

This bulletin discusses the use of banana plantlets produced by tissue culture in Taiwan. The tissue culture programme for banana began in 1983. Originally started to produce plantlets free of Fusarium wilt, the programme is now used to ensure that banana planting materials are free from virus. A total of 26 million plantlets have been produced under the programme. The Bulletin describes the production systems for tissue-cultured plants and discusses the benefits and disadvantages, such as the susceptibility to herbicide damage, of using this type of planting material. Finally the bulletin describes a series of cultural methods to protect disease-free plantlets from virus re-infection in the field. The Bulletin describes how tissue culture technology can be effective and feasible for smallholders, provided the necessary technical support is available. The Bulletin is based on a paper first presented at an international seminar on 'Disease Management of Banana and Citrus: The use and management of disease-free planting materials' held in Davao City, Philippines, on October 14-16, 1998.

S.C. Hwang and H.-J. Su, Extension Bulletin 460, Food and Fertilizer Technology Centre, Taiwan, November 1998.

TBRI, Taiwan provides new banana varieties to INIBAP

The Taiwan Banana Research Institute (TBRI) recently provided two new banana varieties to INIBAP. The two varieties are somaclonal variants of Cavendish, selected by TBRI researchers as being high-yielding and resistant to subtropical race 4 of Fusarium wilt disease. The varieties, GCTCV-106 and GCTCV-247 are presently being virus-indexed by INIBAP. Once indexing is completed, INIBAP will be making these varieties available for world-wide evaluation.

Banana corm rot in north Queensland, Australia

A new form of corm rot has recently been identified on several banana plantations in north Queensland. In addition, a finger rot disease called Mokillo, which occurs occasionally in the region, has also been identified. Banana corm rot appears to be endemic in north Queensland and has previously been described as butt rot caused by *Erwinia carotovora* subsp. *carotovora.* Recently the bacteria *E. chrysanthemi*, *E. chrysanthemi* subsp. *carotovora* and *E.c.* subsp. *atroseptica* have been identified from banana heart rot and corm rot samples from several plantations in the region. The symptom severity appears to be correlated with the *Erwinia* species associated with the infected tissue. This observation suggests that corm rot is probably caused by *E. chrysanthemi* and *E.c.* subsp. *atroseptica*, whereas heart rot is mainly caused by *E. c.* subsp. *carotovora*.

In the case of banana finger rot (Mokillo), the bacteria *E. chrysanthemi* has been successfully isolated from finger rot samples and pathogenicity has been established in banana fruits under laboratory conditions.

This is the first report of *E.c.* subsp. *atroseptica* in bananas and on the ability of *E. chrysanthemi* isolates from corm rot to cause Mokillo.

Source: Australian Bananas Vol. 8, Dec. 1999, Australian Banana Growers' Council Inc.

Biological control of nematodes could become a reality

Researchers in Queensland, Australia have identified potential fungal pathogens of banana nematodes. Following the screening of soil samples from tropical and sub-tropical areas in Queensland and New South Wales, it was discovered that nematode multiplication in the roots of tissue-cultured banana plants was significantly less in plants grown in some untreated soils than in sterilised soils. Fungi extracted from the roots of the bananas were shown to reduce the numbers of burrowing nematodes in pots by 80%. Although much further research is still needed to develop an acceptable method of biological nematode control, the potential for a successful outcome of this work seems to be good.

Source: Bananatopics, Vol. 27, June 1999.

Studies on fixing critical limits of K, Na and K/Na ratio for bananas in saline-sodic soil conditions

In some areas of India, bananas are grown in soils which are classified as "saline-sodic". In such soils bananas suffer from salt injury, which causes external symptoms of marginal chlorosis of the leaves and results in significant yield reduction. In most saline-sodic soils, K/Na ratios are less than one. But in a K-loving crop such as banana, K/Na ratios greater than one are essential.

Fifty soil samples from the rhizosphere and corresponding banana plant tissue samples were collected randomly from saline-sodic soils of the National Research Centre for Bananas (NRCB) farm and from neighbouring farms. The exchangeable K and Na in the soils ranged from 0.31 to 2.54 cmol/kg and from 1.74 to 6.78 cmol/kg respectively. The corresponding yield (bunch weights) were also collected at harvest. The soil and tissue samples were analysed for Na and K concentrations by flame photometer and K/Na ratios calculated.

Correlation coefficients and linear regression equations were calculated for soil and plant K, Na and K/Na against yield. The results obtained indicated that yields gradually increased with increasing Na up to a level of 480 ppm in the soil and 0.47% in the plant tissue. Above this limit, Na had a negative effect on yield. Similarly, the critical limits of soil and plant K concentrations were fixed at 710 ppm and 2.82% respectively.

In conclusion therefore, for optimum yield in saline-sodic soils, the soil should have at least 710 ppm K, not more than 480 ppm Na and the soil K/Na ratio should be at least 1.46. At the same time, the leaves of the banana crop should maintain at least 2.82% K, not more than 0.47% Na and the leaf K/Na ratio should not be less than 5.7.

More information is available from: K.J. Jeyabaskaran, NRCB, Vayalur Road, Trichy 620-017, Tamil Nadu, India.

Medicinal weeds in banana orchards in Chhattisgarh, India

Weed infestation is one of the major constraints to high yields in banana orchards in Chhatisgarh. Farmers generally adopt hand weeding and chemical weed control methods for weed management. However, increasing labour costs and the demand for more organic production methods has resulted in a search for innovative methods for weed management. A series of studies were conducted between 1994 – 2000 by the Department of Agronomy, Indira Gandhi Agricultural University, Raipur. The studies included:

- Identification of existing weed flora of banana orchards
- Listing the medicinal, allelopathic and industrial potential of common weeds
- Searching the potential market for 'useful' weeds.

The study revealed more than 60 weeds with well documented medicinal, industrial or allelopathic uses infesting banana fields. In particular, 10 species were found to be abundant in all districts surveyed, all of which possessed medicinal industrial or allelopathic uses (Table 1).

Table 1. Medicinal uses of 10 common weeds in banana orchards of Chhattisgarh.

Scientific name	Common name	Medicinal use
Cyperus rotundus	Motha	Root is useful in leprosy, thirst, fever, blood diseases, nausea, dysentery, intense itching, epilepsy, opthalmia
Parthenium hysterophorus	Gajar ghas	As a homeopathic drug to cure respiratory problems
Ageratum conyzoides	Mahkua	For skin problems
Euphorbia sp.	Duddhi	For respiratory problems
Chenopodium album	Bathua	For hook worms, Leucoderma
Blumea lacera	Kukurmutta	For bronchitis, fevers, thirst and burning sensations
Achyranthes aspera	Latkana	As stypic, antivenom; in diseases of the digestive system
Calotropis gigantea	Fudhar	For rheumatism and reproductive organ diseases
Datura stramonium	Datura	For respiratory problems
Jatropha curcas	Ratanjot	In diseases of the digestive, respiratory and reproductive systemiis

The study on marketing aspects revealed that these weeds are indeed valuable and more than 300 national and international herbal retailers are eager to purchase these weeds at reasonable prices. The study also revealed that after uprooting the weeds through hand-weeding, and after collecting, processing and selling the parts with the help of village cooperative societies, farmers can earn additional income and recover the cost of hand-weeding.

Effect of post-harvest manipulation of parent pseudostem in the productivity of ratoon crop in banana

An experiment was carried out by researchers at the Agricultural University (Bidhan Chandra Krishi Viswavidyalaya) of West Bengal to investigate the effect on the first ratoon crop of retaining the parent pseudostem after bunch harvest at different heights. The treatments investigated were as follows:

- Cutting height of parent pseudostem:
  - Un-topped
  - Cut at mid-height
  - Cut at corm level.
- Retention of suckers:
  - One sucker per matt
  - Two suckers per matt.

Retention of the un-topped parent pseudostem resulted in an increase in the height and girth of the follower sucker, as well as an increase in the size of fingers and the number of hands/bunch. However this treatment also delayed harvest by 9 days compared to cutting the parent pseudostem at ground level. The retention of two suckers delayed shooting by 17 days, but also resulted in an increased yield. Indeed the highest yield of all treatments (187.6 t/ha) was produced by a combination of two suckers per matt attached to an un-topped mother plant.

Further information available from: Md Abu Hasan, B. Mathew and P.K. Chattopadhyay, Faculty of Horticulture, Agriculture University, Mohanpur, West Bengal, India.

West and Central Africa

The use of mycorrhizae in the control of banana nematodes

Banana nematodes are one of the main constraints to banana and plantain production in West and Central Africa. Researchers at CRBP have been working on banana nematodes for many years, and this research has allowed the principal nematode species to be identified and strategies to control these have been developed. In Cameroon, the main parasitic species at low altitude is *Radopholus similis,* while *Pratylenchus goodeyi* becomes more important at altitudes above 1000 m. Recent research has focused on the use of mycorrhizae (of the genus *Glomus*) isolated in Cameroon, to improve the tolerance of plantains to the two nematode species. Research trials using the plantain cultivar Batard have focused on the performance of both tissue culture and sucker-derived plants, inoculated with the mycorrhizae before field planting. Trials were carried out at both low and high altitude sites.

All plants inoculated with mycorrhizae at both sites showed an increased root mass and higher plant dry matter content than un-inoculated plants. Furthermore, the presence of the mycorrhizae resulted in a reduction of up to 75% of the population of nematodes in the roots of inoculated plants.

Information from Le Courrier du CRBP, No. 65.

Export of plantains to Europe

The transport of plantains from West Africa to the European markets is presently by air. This is expensive and reduces significantly the profit margin for producers. Researchers at CRBP have therefore been investigating the possibilities of conserving plantain fruit at low temperature to allow them to be exported by ship (a journey of around 15 days). Tests were carried out on the varieties French Clair, Bâtard and Big Ebanga. Fruit were collected at various harvest stages and, following fungicide treatment and packing in cartons, the fruit was stored at ambient temperature (25-30°C, 80 – 90% RH) for two days, then placed in a cold chamber (12-14°C, 85-95% RH) for 15 days.

The harvest stage which allowed the fruit to be conserved green for 15 days, without any noticeable decline in quality occurred about one week before the first appearance of a ripening finger on the first hand of French Clair, between one to two weeks for Big Ebanga and two to three weeks for Bâtard. The fruits of the latter two varieties seem to be most suited for the export market, in terms of quality and size.

Source: PlantainInfo No. 39, Oct.-Nov. 1999.

Postharvest handling of bananas and plantains in the rural areas of Enugu state, Nigeria

Poor postharvest handling of bananas and plantains often results in a significant loss of income for rural populations. It was observed that banana and plantain traders in Nsukka agricultural zone in Enugu State of Nigeria sell fruits that have good physical and ripening qualities. A study was therefore carried out to determine traditional handling techniques practised by three communities in this area involved in banana and plantain marketing. Information was obtained from 90 women using a structured questionnaire. The results showed that almost all the respondents were using traditional handling techniques which reduced postharvest losses. The methods employed included:

- Extension of green life of the fruit in a fresh and firm state by daily mist spraying of cold water on the fruit morning and evening.
- Ripening of fruit using *Irvingia smithii* or *I. gabonensis.* (Bananas are placed inside plastic bags with *Irvingia* fruit and kept sealed for a period between 24 and 72 hours, depending on outside temperature.)
- Transport of fruit using baskets lined with leaves to prevent transit injury.

Respondents also highlighted the need for a 'banana house' for storing fruit, located in the coolest area possible. Such a storage area was reported to reduce the temperature around the fruit while increasing the relative humidity of the surrounding area. Handling methods practised also included the immediate de-handing of the banana bunch and placing fruit inside the banana house as soon as possible.

The techniques used are simple and effective and could be readily adapted in other regions.

Further information available from: K.P. Baiyeri and C. Alor. Department of Crop Science, University of Nigeria, Nsukka, Nigeria.

Economic benefits of IPM in Ghana

IITA researchers have been introducing the corm-paring technique as a method of nematode/weevil control to farmers in Ghana. Since the introduction of the technique in 1993, 40% of farmers have adopted it. It was found that the adoption of clean planting material together with improved management practices was profitable over a 3-year period, resulting in returns of US$1300 per hectare, equivalent to US$475 increase when compared to farmers' traditional practices.

Source: IITA Annual Report, 1998.

Latin America and the Caribbean

Black Sigatoka spreads to Haiti

Following the report in INFO*MUSA* 8(2) that black Sigatoka posed a threat to banana production in Haiti, the disease has now been identified there (FruiTrop 67). CIRAD-FLHOR researchers are expecting very soon to confirm the identification of the disease, which appears to have crossed the northern border of Haiti following a marked rainy season at the end of 1999.

For more information, contact: Thierry Lescot, thierry.lescot@cirad.fr

Effect of liquid humus produced by earthworms (*Eisenia foetida*) on the growth of 'Pineo gigante' banana stumps (*Musa* AAA)

The establishment of the initial population of a crop is a most important step which will determine good yields. It is essential to select good quality seed and make sure that the availability of water and nutriments in the soil is adequate to allow a fast and uniform initial growth of the plants (Roberts 1997).

Soil fertility may be preserved through different mechanisms linked to organic matter and through which microorganisms (fungi, bacteria, protozoa, algae, etc.) play an important role in the nutriments' mineralization and stabilisation processes. These microorganisms may themselves, in certain conditions, function as reservoirs which will avoid loss of nutriments due to leaching, volatilisation and/or fixation on humic or inorganic compounds.

These multiple biological processes, in which roots, microorganisms and soil components interact, make inorganic (ionic) compounds available to plants. Incorporation of organic compounds in the soil increases the quantity and activity of soil microorganisms; this suggests managing organic and inorganic fertilisation in commercial plantations as a relatively ecological and economical alternative (Pineda 1996, Sikora cited by Fernández *et al.* 1998). Moreover, the use of inorganic fertilisers leads to a transitory destruction of the soil microbial population, which can be restored by the use of organic fertilisers (Pineda 1996). It is very important to make use of the available knowledge related to soil biological processes and mineralization of labile organic compounds. These play an essential role in the development of a profitable and environment-friendly agriculture, in which the inoculation of microorganisms active at rhizosphere level takes on vital importance (Reyes *et al.* 1995).

However, organic sources are mostly used as soil and/or foliage fertiliser for plants which are already established rather than as a pre-planting treatment. Stumps of the 'Pineo gigante' banana were planted after immersion in a solution of liquid humus produced by the earthworm *Eisenia foetida*, for different concentrations and immersion times.

Liquid humus has a positive effect on precocious budding and on the growth rate of the stumps. The planting material obtained with this pre-planting treatment is more homogeneous and stronger than non-treated stumps. Indeed, this treatment allows faster establishment of the plant and enables it to better exploit the nutriments present in the soil solution. Its type of action is not clearly explained yet but it can already be inferred that in a way or another, it activates physiological mechanisms which have a notable and direct influence on banana's development and growth, as is expressed by plant vigour. It is important to conduct further research on this subject and to study physiological aspects more closely.

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Preliminary results provided by Gustavo Martínez, Omar Tremont, Rafael Pargas and Edwuar Manzanilla, FONAIAP/CENIAP, Apartado postal 4663, Maracay 2101, Venezuela.

Eastern and Southern Africa

Spread of black Sigatoka in the Indian Ocean region

During the 1990s black Sigatoka spread from East Africa to the Comoros archipelago, being confirmed in Mayotte in 1995. The disease has since spread to all the plantations on these islands. The presence of the disease is suspected in Madagascar and samples are presently being analysed by CIRAD-FLHOR for confirmation.

Source FruiTrop 67, March 2000.

Banana streak disease is present in Réunion

Banana was introduced in the island of Réunion in about 1668 by Dutch seafarers (Rivals 1960). No indigenous varieties have been listed but several cultivars have been introduced since then. They belong to the Sucrier, Cavendish, Silk, Pome and Bluggoe subgroups. 'Figue Rose' (Red sub-group), a few plantain varieties and a number of ornamental bananas (*Ensete* sp., *M. balbisiana*, *M. ornata, M. zebrina* and *M. velutina*) are also grown in family gardens.

The most commonly cultivated clones belong to the Cavendish subgroup ('Valéry' and 'Petite Naine' and, more recently, 'Grande Naine' and 'Williams'). Bananas belonging to the Silk and Pome subgroups are usually planted at the edge of sugar cane fields and generate additional income for households when the other varieties are not available on the market. Semi-intensive fields are found mainly on the north-east coast and in the south, where there is more rainfall (Anon. 1998). Average farm area does not exceed 2 to 3 hectares and a total of some 200 hectares is under banana (Figure 1), on an island with a population of 750 000 inhabitants. It is estimated that Réunion has a total of 500 hectares under banana, when isolated micro-fields are included (Agreste 1998).

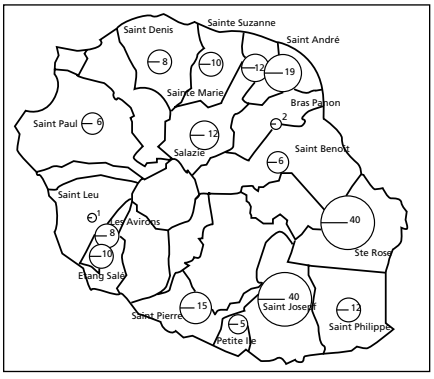

***Figure 1**. Geographical distribution and hectareage of cultivated bananas.*

Yields vary from 10 to 30 tonnes per hectare. Production is reserved for local consumption only.

The banana borer (*Cosmopolites sordidus*) is the main pest. Yellow and black Sigatoka have not been observed. Attacks by *Fusarium* sp. have been observed on plants belonging to the Silk subgroup.

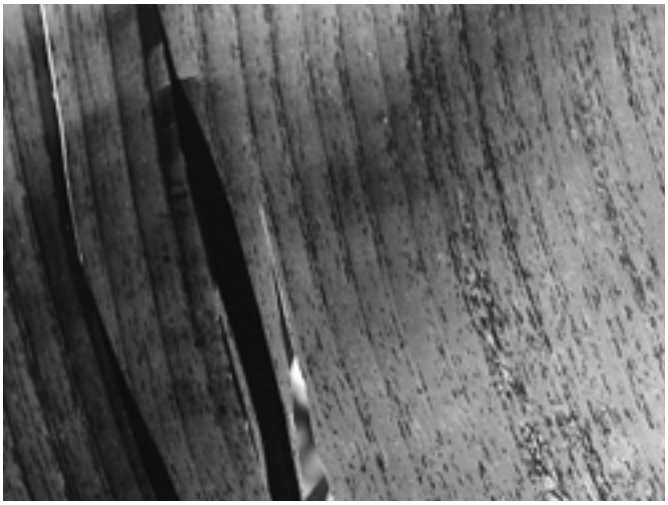

Figure 2. *Symptoms fo BSV on a banana leaf.*

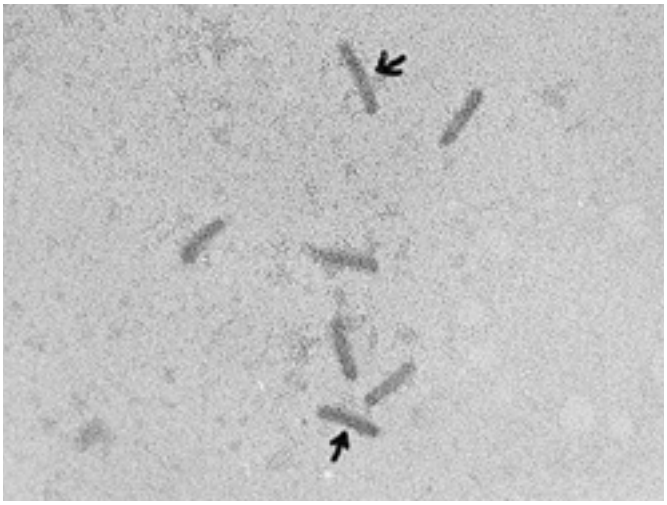

Figure 3. *Bacilliform particles of BSV (x 29 000).*

Only 'Petite Naine' plants display symptoms of banana streak disease, with the crinkling of portions of leaf and subsequent rosetting of the plant (Figure 2). Bunches are deformed and small. Other Cavendish subgroup bananas planted in the same fields do not display symptoms.

This cultivar, whose local name is 'Gabou', is rarely grown intensively, although its potential yield is satisfactory in the climatic conditions of Réunion. In contrast, it is often planted in fruit gardens.

A leaf sample was indexed at the CIRAD virology laboratory. Observation using immuno-electron microscopy with the polyvalent serum developed by Lockhart against banana streak virus (BSV) revealed bacilliform particles (Figure 3). The banana plants concerned are therefore infected by BSV.

This viral disease was first described in Morocco (Lockhart 1986) and then in numerous banana production zones and in the Indian Ocean area: Mauritius, Madagascar, East and southern Africa and Australia (Caruana 1993). Banana plants displaying these symptoms were inventoried in all the cultivation areas in Réunion (see map). Most growers had observed these symptoms «for a very long time» without relating them to the presence of a disease. Indeed, the diseased plants do not display any more visible symptoms such as necrosis or wilt.

The proportion of diseased plants in the infected fields varies from 20 to 50%. Spread of the disease does not seem to be related to an animal vector. No scales are observed on the plants. As banana streak virus is not spread by tools, it would seem that the only way in which it can spread is via the planting of infected suckers.

In collaboration with the Réunion Plant Protection Service (*Service de la Protection des Végétaux*), farmers are being informed of this manner of spread of the disease, are trained in the identification of infected plants and are being asked not to use diseased suckers for replanting and at best to destroy diseased mats by application of a systemic insecticide. The use of plants grown by tissue culture and indexed for BSV is also a recommended method.

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Thesis

The interdependence of root and shoot development in banana (*Musa* spp.) under field conditions and the influence of different biophysical factors on this relationship

PhD Thesis submitted at KUL, Leuven, Belgium, February 2000.

Guy Blomme

Banana and plantain (*Musa* spp.) are important crops for the small-scale farmer in the humid and subhumid tropical regions of the world. Intensive breeding efforts are underway in this crop but all focus on the improvement of aboveground parameters. Yet the *Musa* root system is crucial for nutrient and water uptake, plant support and production of plant growth regulators. Past research on *Musa* root systems was limited to high value export dessert bananas and few investigations have been carried out on the root system of plantains, cooking bananas or *Musa* hybrids. Therefore, a comprehensive study of the *Musa* root system up to the first ratoon

was executed. This involved the investigation of 46 genotypes belonging to all *Musa* groups and ploidy levels to provide background support for the genetic improvement of plantains and bananas.

The relationship between the root and the shoot system of *Musa* plants was assessed using correlation and principal component analysis. Strong positive correlations were observed between root and shoot growth of the mother plant during the early and mid-vegetative phase. However, these correlations were less pronounced during the reproductive phase, most probably due to enhanced root senescence and increased competition between the mother plant and its suckers (i.e. lateral shoots).

Growth curves were drawn for different root and shoot traits. The shoot-root ratio increased during the vegetative phase. For example, the root system of *in vitro*-derived plants comprised up to 40% plant dry matter during the early vegetative phase but less than 15% during the reproductive phase. Leaf area as well as root system size decreased during the reproductive phase.

Variability in root system size is required to conduct a breeding programme aimed at root system improvement. An increase in root system size was observed with higher ploidy levels.Variability in lateral root traits between genotypes could not be assessed due to strong micro-environmental influences on lateral root growth.

Shoot and root growth are influenced by the type of vegetative planting material. For example, sucker-derived plants produced a larger root system during the mid-vegetative phase compared to *in vitro*-derived plants. This may be due to the larger corm size of the sucker-derived planting material. The root system size of plants at flower emergence was however similar for both types of planting material.

Methods were developed for fast and non-destructive root system assessment. Root traits were estimated from easily measurable shoot parameters. In addition, soil core sampling (assessing less than 3% of the mat root system) could give adequate information on the root system size of a complete mat. This method requires only 5% of the time needed to excavate and assess the root system of the entire mat.

We observed significant effects of soil type, climate, nematode infestation and leaf area reduction on the root system size. For example, a nematode infection reduced the root system size up to 70% for susceptible genotypes. However, the reduction in shoot growth was generally less than the reduction in root growth. Nematode-susceptible genotypes will thus have a high shoot-root ratio making them increasingly susceptible to toppling.

Results from this study provide an in-depth view on *Musa* root system development and growth, and should facilitate the research programmes of both nematologists and breeders. ■

Neem seed derivatives for the management of the banana weevil, *Cosmopolites sordidus* Germar (Coleoptera: Curculionidae) and parasitic nematode complex

PhD Thesis submitted to Kenyatta University, Nairobi, Kenya, July 1999.

Thaddée Musabyimana

Tests were conducted during the period May 1996 to February 1999 in the laboratory at ICIPE's Mbita Point field station (MPFS) and in the farmers' fields in western Kenya, a prime banana growing area. Neem seed powder (NSP), neem kernel powder (NKP), neem cake (NC) and neem oil (NO) containing 4000, 5500, 5800 and 850 ppm of azadirachtin A, respectively, were used as such or in aqueous form.

Laboratory experiments: in choice tests, 48 h after release, less than 30% of weevils settled under neem-treated banana while more than 50% settled under untreated corms. In a feeding test, weevil larvae caused little damage to the neem-treated corms while it caused heavy damage to the untreated ones. This indicates a strong antifeedant effect of neem on *C. sordidus*. Also, females laid 3-10 times fewer eggs in neem-treated than in the untreated corms. The egg hatchability was less than 25% in neem treatments and more than 50% in the controls. Neem treatments also inhibited larval growth and development: 40 to 60% of 2nd-instar larvae died in 14 days when confined to neem-treated banana pseudostems; the survivors were small in body size and weighed 4 to 6 times less than those in the control. The higher the concentration, the greater was the effect of neem materials.

Efficacy of neem materials against *C. sordidus* and nematodes was evaluated under controlled pest infestation levels in the drums at MPFS. Effective methods, frequency and rates of application of selected neem materials were determined at MPFS and in farmers' fields, under different levels of soil fertility and pests infestation. In those trials, Nakyetengu (AAA-EA), a highly susceptible cultivar to the above pests was used.

Outdoors and fields experiments: in an outdoors experiment, NSP, NKP and NC were applied at 100 g/plant at planting to pared or unpared banana suckers planted in 100 or 200 L drum's capacity and inoculated with 2000 mixed nematodes and five pairs (females and males) of the banana weevil per drum. A treatment with suckers dipped in NO-extract was also included. Compared with the control, 10 months after treatments, neem materials significantly reduced the nematode population and weevil damage on par with Furadan applied at 40 g/plant. In addition, NSP-and NC-treated unpared suckers supported much fewer nematodes than pared treated suckers with the same neem products, obviating the need for paring of suckers. However, NKP and NO applications were toxic to the banana plant.

Soil application of powdered NSP or NC was more effective than their application in aqueous forms. Application of NSP or NC at planting time and then at 1, 2, 3, or 4-month intervals to plants grown under controlled pest infestations in drums significantly reduced nematode density and the weevil damage. Similarly, in the farmersÕ fields, soil application of NSP or NC at 60, 80 and 100 g/mat at planting and then at 4-month interval significantly

reduced the weevil and nematode damage, and increased yields by 27-50% over the control (first crop) and by 30-60% in the second crop. Furadan increased the fruit yield by 27% over the control in the first crop but dropped down to -2% in the second crop. Even under low soil fertility and high pest infestation levels, the neem treatments controlled the pests and markedly increased the yield 7 to 10 times more than that in the control. The application of NSP or NC at 200 to 400 g/mat at 6-month intervals was toxic to the banana plant.

Depending on the soil fertility and doses of application, net gain over the control obtained with application of NSP or NC ranged from US$ 70 and US$ 800 per hectare. However, a loss of US$ 700 per hectare was observed with the Furadan application. Neem application at doses higher than 200 g/mat was uneconomical. The beneficial effects of neem seed materials application on banana plant growth and development, pest control, and implications of these findings in banana pest management and further areas of investigation are discussed. ■

Books, etc...

Evaluating bananas: a global partnership. Results of IMTP Phase II

Compiled by G. Orjeda
ISBN: 2-910810-38-0

For the International *Musa* Testing Programme (IMTP) Phase II, germplasm was evaluated for resistance to black Sigatoka (*M. fijiensis*), yellow Sigatoka (*M. musicola*) and Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*). The majority of IMTP Phase II trials were planted during 1996 and 1997. The first part of this publication provides a synthesis of final results (an overview of the final report and summary of results have already been published in INFO*MUSA* Vol. 8, No. 1, pp. 3-10). In the second part, full results are given for Sigatoka sites in Cameroon, Colombia, Costa Rica, Honduras, Nigeria, the Philippines, Tonga, and Uganda, and for Fusarium wilt (*Foc*) sites in Australia, Brazil, Honduras, Indonesia, Malaysia, the Philippines, South Africa, Spain, Taiwan, and Uganda.

Bananas

ISBN: 2-910810-37-2

This 16-page booklet, produced originally in French for the 1998 Paris Agricultural Fair has now been translated in English. It presents information on all the aspects of the crop: origin, diversity, economic importance, role in food security, commercialization, pests and diseases, research, processing. The brochure is available from INIBAP Headquarters in Montpellier.

Announcements

IV international scientific seminar of plant protection

The Convention Center of Varadero Beach, Matanzas, Cuba. June 11th -15th of 2001

The *Instituto de Investigaciones de Sanidad Vegetal* (INISAV) and the *Centro Nacional de Sanidad Agropecuaria* (CENSA) organize, from the 11th to 5th of June of the 2001, the IV International Scientific Seminar of Plant Protection that will take place in the Palace of Conventions at Varadero Beach.

In this forum, investigators, professors, extensionists and officials of different countries will discuss the problems and more recent results, as well as the tendencies of the plant protection for the new millennium.

The scientific programme will include plenary sessions, workshops, of which one entitled *Workshop on banana pests and diseases: current situation and challenges for the new century*, symposia and meetings, besides sessions of posters and commercial exhibitions.

To get more detailed information please contact the executive secretaries of the Organizing Committee:

Ileana Sandoval Ramírez
Instituto de Investigaciones de Sanidad Vegetal. (INISAV)
Calle 110 #514. between 5ta B and 5ta F. Playa. C. P 11600.
La Havana. Cuba
Fax: (537) 240535
E-mail: inisav@ceniai.inf.cu
Maricela Díaz Rodríguez
Centro Nacional de Sanidad Agropecuaria (CENSA)
PO Box 10. San José de las Lajas,
La Havana. Cuba
Fax: (5364) 63897
E-mail: mdiaz@id.censa.edu.cu

All those interested to get more information on the «Workshop on banana pests and diseases: current situation and challenges for the new century» are invited to contact Dr Luis Pérez Vicente, convener of the workshop at the e-mail:
inisav@ceniai.inf.cu or
cnsv@ceniai.inf.cu

The International Foundation for Science - Call for research grant applications from developing country scientists

The International Foundation for Science (IFS) provides support to young scientists of merit in developing countries by awarding research grants and providing grantees with additional services such as travel grants and purchasing assistance.

Research grants are awarded up to a maximum value of USD 12,000 for a period of one to three years and may be renewed twice. They are intended for the purchase of equipment, expendable supplies, and literature. Applicants must be citizens of, and carry out the research in, a developing country. They should also work at a university or national research institution in a developing country (countries in Europe, including Turkey and Cyprus, or the former Soviet Union do not qualify for support). As well as being under the age of 40 (under 30 for applicants from China) and at the start of their research career, candidates must possess a higher academic degree, which should be at least an MSc or equivalent.

The IFS supports projects dealing with the management, use, and conservation of biological resources. The Foundation organizes its activities into six Research Areas, viz Animal Production, Aquatic Resources, Crop Science,

Food Science, Forestry/Agroforestry, and Natural Products.

For further information and application forms in English and French write to:
IFS, Grev Turegatan 19, S-114 38
Stockholm, Sweden
Fax: + 46-8-54581801
Email: info@ifs.se
Http://www.ifs.se

INIBAP News

First *MUSA*LAC meeting

On June 6, 2000, in Cartagena de Indias, Colombia, 14 national research and development institutions representing their respective countries (Bolivia, Brazil, Colombia, Costa Rica, Cuba, Ecuador, Honduras, Jamaica, Mexico, Panama, Peru, Puerto Rico, Dominican Republic and Venezuela) and 4 regional/international institutions (CATIE, CIRAD, IICA and INIBAP) signed, in the framework of FORAGRO, an Agreement for the Establishment of the Plantain and Banana Research and Development Network for Latin America and the Caribbean (*MUSA*LAC).

The general objective of *MUSA*LAC is to increase the productivity and competitiveness of the plantain and banana agribusiness through the enhancement of scientific and technological activities; this involves strengthening of national research and development systems, integration of stakeholders, priority setting and coordination of actions in Latin America and the Caribbean.

*MUSA*LAC's specific objectives are:

- To bring together conventional and non-conventional genetic improvement programmes and to urge them to focus on the rapid development of improved *Musa* varieties with a broad genetic base and consumer acceptability and to make these available to farmers through national research and development programmes.
- To develop and to extend participatory integrated management systems addressing priority problems using a sustainable and profitable approach.
- To generate and to transfer agronomic and post-harvest management technologies to increase the crop's productivity and sustainability.
- To favour farmer's overall development by improving his/her competitiveness and to promote an increase of the demand for *Musa* products and by-products.

MUSA*LAC* organization

*MUSA*LAC is composed of:

- **a Steering Committee,** comprising a representative of one institution of each member country, which will determine the Network's policies, action plans and projects in the medium and long term. This Committee will meet once a year. Dr Altagracia Rivera de Castillo, from CEDAF, Dominican Republic was elected President of this Committee; Drs Rodrigo Aveldaño, from INIFAP, México, and Alvaro Uribe, from CORPOICA, Colombia, were elected Vice-presidents.
- **an Executive Committee** whose responsibility will be to coordinate and follow-up on *MUSA*LAC's general action plan and annual workplans. Dr Franklin E. Rosales, Coordinator of INIBAP for Latin America and the Caribbean was appointed Executive Coordinator.
- **National Nodes**, consisting mainly of public and private national institutions whose mandate and responsibilities include plantain and banana research and development at the national level, as well as coordination mechanisms (for example national networks, support groups, etc.).

*MUSA*LAC will stimulate the participation of international or regional technical and financial cooperation organizations related to plantain and banana research and development, whose mandates coincide with the Network's objectives.

In the first stage, priority will be given to four thematic components:

- Genetic improvement
- Integrated pest management
- Crop management
- Socioeconomic development.

After signing the Agreement, participants split into four thematic groups to elaborate, with the help of Dr Jorge Saravia from CIAT, a logical framework for four subjects identified as regional priorities, defined in order to develop projects for *MUSA*LAC.

The event was inaugurated by Dr Juan Lucas Restrepo, Director of the Agrarian Development Office of Colombia's National Planning Department. Lectures were given by Drs Enrique Alarcon from IICA, Costa Rica, Miguel Gomez Lim from CINVESTAV, Mexico and Carlos Quiros from CIAT, Colombia, focusing on: "Latin America and the Caribbean agricultural scenarios addressed from a technological perspective"; "Plant biotechnology in Latin America: opportunities and challenges"; and "Participatory research", respectively. Two presentations were also made by IPGRI-INIBAP staff members on PRO*MUSA* and IMTP (Jean-Vincent

The participants of the first MUSA*LAC meeting.*

Franklin Rosales, INIBAP regional coordinator, signs the MUSALAC *Agreement.*

Escalant) and on the global INIBAP information system (Claudine Picq).

New staff at INIBAP

INIBAP has recently recruited six new staff members.

Guy Blomme, a Belgian citizen, is an Agricultural Scientist with a specialisation in crop husbandry and tropical agriculture. He completed two years of postgraduate studies in Tropical Agriculture at the Ecole supérieure d'agronomie tropicale in Montpellier. He has just successfully defended his PhD at KUL, Leuven, Belgium. The title of the thesis was "The interdependence of root and shoot development in banana (*Musa* spp.) under field conditions and the influence of different biophysical factors on this relationship". The research was carried out at the IITA Onne High Rainfall station where Guy spent almost five years, and was supervised by Prof. R. Swennen and Dr A. Tenkouano from IITA. Guy took up his new position of Associate Scientist, *Musa* Technology Transfer, at the INIBAP Regional Office for Eastern and Southern Africa, Kampala, Uganda at the beginning of February 2000.

Max Ruas, a French citizen, has a Masters' Degree in Biology (*Maîtrise de biologie des organismes et des populations*) and a post-Masters' Degree in Computers Sciences (*Informatique appliquée aux organisations*), both from the University of Montpellier. Max has previous professional experience as a Data Manager in Biology and as a Computer Programmer. Max took up his new position of Computer Services Assistant at the INIBAP office in Montpellier on 28 February 2000.

Deborah Karamura, a Ugandan citizen, has been working for the National Agricultural Research Organisation (NARO) Uganda, as a banana taxonomist and a germplasm specialist since January 1994. She holds a Doctorate in crop taxonomy, a Masters degree in Pure and Applied Taxonomy (University of Reading) and a Bachelor of Science degree in Botany and Zoology (Makerere University). Deborah has recently been recruited by INIBAP as a *Musa* Germplasm Specialist for the *Musa in situ* Conservation Project which is being implemented in Uganda and Tanzania, and she is based at INIBAP's Regional Office in Kampala. Deborah will be responsible for various aspects of the project, including documenting cultivar diversity in the region and supporting and training NARS personnel in methodologies for germplasm characterization. Deborah will also commit 30% of her time to NARO germplasm research activities. In the project, Deborah will work closely with staff from the Uganda and Tanzania NARS, IITA, ICIPE and a number of NGOs.

Charlotte Lusty, a British citizen, has a BSc Honours Degree in Biological Sciences (Zoology) from Edinburgh University (1988-1991). After graduating from University, Charlotte spent over two years working on various field-based projects in the UK, Kenya and Tanzania. Since 1994, she has been working for the World Conservation Monitoring Centre (WCMC), devoted mainly to the management of information resources in the plants programme. She acquired wide experience in species data management, liaison within a global network of experts, workshop organisation and production of materials and publications. Charlotte took up her new position of Impact Assessment and Public Awareness Specialist at the INIBAP office in Montpellier as of 5 June 2000. Charlotte's duties at INIBAP will include: the evaluation and synthesis of scientific data and information, preparation of public awareness materials for the INIBAP programme and assistance to the INIBAP Regional Coordinators in the area of public awareness/impact assessment, as well as assistance with the production of INIBAP publications.

Luis Pocasangre, a Honduran citizen, graduated from the Tropical Agriculture Research & Higher Education Centre, Turrialba, Costa Rica in 1992 (MSc in Plant breeding, emphasis on biotechnology) and from the *Universidad Nacional Autónoma de Honduras* (BS Agronomy) in 1988. Over the last 10 years, Luis has acquired wide experience in various laboratories: pathology, nematology, tissue culture, biotechnology, plant physiology and germplasm conversation laboratories. Since 1996, he has worked as a Research Assistant at the *Universität Bonn*, where he was responsible for the biological enhancement of tissue culture plantlets for banana production systems. Luis will be defending his PhD thesis in plant pathology/nematology at the *Institut für Pflanzenkrankheiten, Universität Bonn* in June 2000, and will be taking up his new position of Associate Scientist, Technology Transfer, as of 1 July 2000. Luis will be assisting the INIBAP Regional Coordinator for Latin America and the Caribbean.

Charles Eledu, a Ugandan citizen, has an MSc in Soil Surveying from the International Institute for Aerospace Surveys and Earth Sciences, the Netherlands, and a BSc (Hons) in Agriculture from the University of Makerere, Uganda. For the past three years he has been working as a GIS Research Associate at the International Centre for Tropical Agriculture (CIAT), in Uganda, where he was responsible for developing and implementing a bean database for

Guy Blomme

Max Ruas

Deborah Karamura

Charlotte Lusty

Luis Pocasangre

Charles Eledu

Africa. He has also provided GIS support for the IITA banana programme in Uganda. Charles has recently been recruited as GIS Expert for the banana baseline information project being implemented in Eastern and Southern Africa by INIBAP.

Departure of Gisella Orjeda

Gisella Orjeda joined INIBAP in May 1996 as *Musa* Germplasm Improvement Scientist. Gisella, a Peruvian national, took over responsibility for the second Phase of the International *Musa* Testing Programme and, during her time with INIBAP, was also actively involved in the initiation of the Global Programme for *Musa* Improvement, PRO*MUSA*. Gisella travelled extensively in relation to her work on the IMTP, visiting the evaluation sites around the world and working with participating programmes in the collection and analysis of evaluation data. One of Gisella's major achievements during her time with INIBAP was the development of the IMTP database, which now contains information on over 30 candidate clones available for evaluation in future IMTP trials. Gisella always put great emphasis on ensuring the statistical validity of data generated by IMTP trials and worked hard on developing standard formats for data collection to allow easy comparison of data collected from different sites. On completion of the Phase II trials, Gisella performed a full statistical analysis of results from 17 sites and ensured the publication of the final report of IMTP II, which is now available from INIBAP.

After three years of working as a research coordinator with INIBAP, Gisella decided that she wished to return to hands-on research. Accordingly, her last six months with INIBAP were spent working in collaboration with CIRAD on the molecular characterisation of banana cells derived from protoplast fusion experiments. On completion of this short research project, Gisella left INIBAP in order to pursue her research career.

The staff of INIBAP would like to take this opportunity to wish Gisella all the very best for the future.

15th anniversary

This year INIBAP is celebrating its 15th Anniversary. In recognition of this anniversary, a number of special activities and initiatives are being undertaken by INIBAP. These include the translation of the beautiful 'Bananas' brochure from French into English and the production of a series of factsheets dealing with bananas as a global food crop and INIBAP's role in *Musa* research and development.

The anniversary will be formally marked at the next global PRO*MUSA* meeting, due to take place in Thailand in November. This meeting will coincide with a national banana symposium and exhibition.

In looking back over the last 15 years, it can be seen that in this short period, INIBAP has seen remarkable growth and evolution. It has developed from a small independent institute with less than 10 staff, to becoming a significant programme of the CGIAR, with over 40 staff members who are today located in seven countries around the world. At the present time, INIBAP is actively supporting more than 40 banana research projects which are being carried out in 30 countries world-wide, while more than 50 countries are members of regional networks coordinated by INIBAP.

External Review of INIBAP

During February and March 2000, the INIBAP programme was reviewed by an external panel of experts commissioned by IPGRI. The review panel consisted of Dr Claude Fauquet (Director, ILTAB, USA), Prof. Joseph Mukibi (Director-General, NARO, Uganda), Dr Michel de Nucé de Lamothe (President Agropolis, France) and Prof. Dolores Ramirez (University of the Philippines, Panel Leader).

The panel members each visited an INIBAP regional office and two or three of the NARS in the different regions. The team also visited the INIBAP genebank in Belgium and INIBAP Headquarters in Montpellier.

The review panel reported very favourably on the INIBAP programme, both in terms of the regional and global activities being undertaken. Particular strengths were noted in the areas of germplasm exchange, germplasm improvement, documentation and training. The review panel also commended INIBAP for its way of operating and noted that networking and outsourcing allows an impressive amount of work to be conducted by a small team.

Several areas for increased activity in the future were identified, including the need for a conservation strategy for a more complete coverage of the whole *Musa* genepool, and greater use of *Musa* diversity in breeding and improvement activities. INIBAP is already taking steps to address these and other issues raised by the review team.

Finally, the review panel noted that, compared to the global importance of the crop, banana research is limited, and this is mainly due to the low level of funds devoted to such research. However, it was recognised that banana research needs at the international level are best addressed through a networking approach and the panel believed that the structure developed by INIBAP is well adapted to meet future needs. Furthermore, the panel recommended that IPGRI brings to the CGIAR's attention the INIBAP model as a scheme for addressing concerns of other commodities or systems.

EXPO 2000

EXPO 2000, which takes place in Hannover, Germany from 1 June to 31 October has taken as its key theme «Humankind - Nature – Technology - A whole new world». One of the unique features of EXPO 2000 is that it does not take place in Hannover alone. EXPO 2000 is considered to exist wherever people develop and realise ideas for the future. One of the ways EXPO 2000 is aiming to become a World Exposition in the true sense of the word is through a completely new concept entitled "Projects around the World". INIBAP's genebank has been selected by EXPO 2000 as one of these 'Projects around the world'.

By participating in EXPO 2000, INIBAP is hoping to raise the profile of bananas as a staple food crop. INIBAP will emphasise the fact that more than 85% of the world-wide banana harvest of 88 million tonnes is produced by small-scale farmers, almost exclusively for local consumption. Bananas are essentially a staple food crop, and this is a fact that INIBAP will be promoting at EXPO 2000.

INIBAP Web site

As reported in the last issue of INFO*MUSA (*Vol. 8,2), INIBAP has recently launched a new Web site which provides a wide range of information about INIBAP as well as on-line access to INIBAP's databases and selected publications. We are pleased to announce that the Web site is now available in three languages, English, French and Spanish.

Recent additions to the site include the English and Spanish versions of the report of the International Workshop on the "Production and Marketing of Organic Bananas by Smallholder Farmers", which was held in the Dominican Republic in November 1999, and information about the upcoming International Symposium on the Molecular and Cellular Biology of Bananas and the next global PRO*MUSA* meeting.
The Web site address is:
http://www.inibap.org

INIBAP addresses

• Headquarters:
Parc Scientifique Agropolis II
34397 Montpellier Cedex 5
FRANCE
e-mail: inibap@cgiar.org
http://www.inibap.org

Director
Dr Emile FRISON
e-mail: e.frison@cgiar.org

Plant Genetic Resources Scientist
Dr Jean-Vincent ESCALANT
e-mail: j.escalant@cgiar.org

Germplasm Conservation Scientist
Ms Suzanne SHARROCK
e-mail: s.sharrock@cgiar.org

Head Information/Communications
Ms Claudine PICQ
e-mail: c.picq@cgiar.org

Officer in charge MGIS
Ms Elizabeth ARNAUD
e-mail: e.arnaud@cgiar.org

Financial Manager
Mr Thomas THORNTON
e-mail: t.thornton@cgiar.org

• Regional Office for Latin America and the Caribbean
Regional Coordinator
Dr Franklin E. ROSALES
Associate Scientist,
Musa technology transfer
Luis POCASANGRE
C/o CATIE
Apdo 60-7170 Turrialba,
COSTA RICA
Tel/Fax: (506) 556 2431
e-mail: inibap@catie.ac.cr

• Regional Office for Asia and the Pacific
Regional Coordinator
Dr Agustín MOLINA
C/o Collaborator Center IRRI
College, Laguna 4031
PHILIPPINES
Fax: (63 49) 536 05 32
e-mail: a.molina@cgiar.org

• Regional Office for West and Central Africa
Regional Coordinator
Dr Ekow AKYEAMPONG
Associate expert entomology:
Stjin MESSIAEN
C/o CRBP - BP 12438
Douala, CAMEROON
Fax: (+237) 42 91 56
E-mail: inibap@camnet.cm

• Regional Office for Eastern and Southern Africa
Regional Coordinator
Dr Eldad KARAMURA
Associate Scientist, Technology transfer
Guy BLOMME
Po Box 24384
Kampala, UGANDA
Fax: (+256-41) 28 69 49
e-mail: inibap@imul.com

• INIBAP Transit Center (ITC)
Officer in charge
Ms Ines VAN DEN HOUWE
Katholieke Universiteit Leuven
Laboratory of Tropical Crop Improvement
Kardinaal Mercierlan 92
B-3001 Heverlee – BELGIUM
Fax: (32 16) 32 19 93
e-mail: ines.vandenhouwe@agr.kuleuven.ac.be

• Associate Experts, Nematology
Ms Inge VAN DEN BERGH
C/o VASI
Van Diem, Than Tri
Hanoi, VIETNAM
Fax: (84) 4 861 39 37
e-mail: ingegeert@fpt.vn
Mr Thomas MOENS
C/o CORBANA
La Rita Research Station
Apdo 390-7210
Guápiles, COSTA RICA
Fax: (506) 763 30 55
e-mail: investigaciones@corbana.com

Instructions to authors

Typescripts should be prepared in English, French or Spanish and submitted in duplicate to the Managing Editor. They should be double-spaced throughout. All pages (including tables figures, legends and references) should be numbered consecutively. Include the full name of all the authors of the paper, together with the addresses of the authors at the time of the work reported in the paper. Indicate also the author nominated to receive correspondence regarding the paper.

If the typescript was prepared on a computer, please send a copy on diskette (or by e-mail) along with the printed ones, indicating the name and version of the wordprocessor used.

- **Abstracts:** An abstract not exceeding 200-250 words should be sent in the same language as the typescript, as well as translations (including the title) into the two other languages, if this is possible.
- **Acronyms:** These should be written in full the first time they appear in the text, followed by the acronym in parenthesis.
- **References:** All literature references made in the text should be referred to by author(s) and year of publication (e.g.: Sarah *et al.* 1992, Rowe 1995). A list of references, in alphabetical order, should be provided at the end of the text.

Please follow the style shown below:

Periodicals: Sarah J.L., C. Blavignac & M. Boisseau. 1992. Une méthode de laboratoire pour le criblage variétal des bananiers vis-à-vis de la résistance aux nématodes. Fruits 47(5): 559-564.

Books: Stover R.H. & N.W. Simmonds. 1987. Bananas (3rd edition). Longman, London, United Kingdom.

Articles (or chapters) in books: Bakry F. & J.P. Horry. 1994. *Musa* breeding at CIRAD-FLHOR. Pp. 169-175 *in* The Improvement and Testing of *Musa*: a Global Partnership (D.R. Jones, ed.). INIBAP, Montpellier, France.

Tables: These should be numbered consecutively and referred to by these number in the text. Each table should include a title.

Illustrations: These should be numbered consecutively and referred to by these numbers in the text. Each illustration should include a clear and simple caption.

Graphs: provide the corresponding raw data with the graphs.

Drawings: provide originals if this is possible.

Black and white photographs: provide them on bright paper and with good contrast.

Colour photographs: provide good quality proofs and films or original slides.

Note: When plant material used for the experiments reported originates or is registered in the INIBAP genebank, its accession number (ITC code) should be indicated within the text or in a tabular form.

Thank you in advance for following these instructions
This will facilitate and accelerate the editing work.

www.inibap.org

Publications from INIBAP

The following publications are available from headquarters:

CIRAD/INIBAP 2000. Bananas.

INIBAP. 2000. G. Orjeda (compil.). Evaluating bananas: a global partnership. Results of IMTP Phase II.

INIBAP/EARTH/IDRC. 1999. F.E. Rosales, S.C. Tripon & J. Cerna (eds). Organic/environmentally friendly banana production. Proceedings of a workshop held at EARTH, Guácimo, Costa Rica, 27-29 July 1998 (*in press*).

INIBAP/CRBP/CTA/CF. 1999. C. Picq, E. Fouré & E.A. Frison (eds). Bananas and food security/Les productions bananières: un enjeu économique majeur pour la sécurité alimentaire. Proceedings of an International Symposium held in Douala, Cameroon, 10-14 November 1998.

INIBAP/FHIA. 1999. F.E. Rosales, E. Arnaud & J. Coto (eds). A tribute to the work of Paul H. Allen: a catalogue of wild and cultivated bananas.

INIBAP/RF/SDC. 1999. E.A. Frison, C.S. Gold, E.B. Karamura & R.A. Sikora (eds). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM held in Nelspruit, South Africa, 23-28 November 1998.

INIBAP 1999. E. Akyeampong (ed.). *Musa* Network for West and Central Africa. Report of the second Steering Committee meeting held at Douala, Cameroon, 15-16 November 1998.

INIBAP 1999. Annual Report 1998.

INIBAP 1999. K. Shepherd. Cytogenetics of the genus *Musa.*

INIBAP 1998. E. Akyeampong (ed.). *Musa* Network for West and Central Africa. Report of the first Steering Committee meeting held at Douala, Cameroon, 8-10 December 1997.

INIBAP 1998. E.A. Frison & S.L. Sharrock (eds). Banana streak virus: a unique virus-*Musa* interaction? Proceedings of a workshop of the PRO*MUSA* virology working group held in Montpellier, France, 19-21 January 1998.

INIBAP 1998. C. Picq (ed.). Segundo seminario/taller de la Red regional de información sobre banano y plátano de America Latina y el Caribe. San José, Costa Rica, 10-11 July 1997.

INIBAP 1998. B.K. Dadzie. Post-harvest characteristics of black Sigatoka resistant banana, cooking banana and plants hybrids. INIBAP Technical Guidelines 4.

INIBAP 1998. G. Orjeda in collaboration with the PRO*MUSA* working groups on Sigatoka and Fusarium. Evaluation of *Musa* germplasm for resistance to Sigatoka diseases and Fusarium wilt. INIBAP Technical Guidelines 3.

INIBAP/ACIAR 1997. E. Arnaud & J.P. Horry (eds). *Musa*logue, a catalogue of *Musa* germplasm: Papua New Guinea collecting missions 1988-1989.

INIBAP/CTA/FHIA/NRI/ODA 1997. B.K. Dadzie & J.E. Orchard. Post-harvest Routine Screening of Banana and Plantain Hybrids: Criteria and Methods. INIBAP Technical Guidelines 2.

INIBAP/CTA 1997. P.R. Speijer & D. De Waele. Screening of *Musa* Germplasm for Resistance and Tolerance to Nematodes. INIBAP Technical Guidelines 1.

INIBAP/The World Bank 1997. E.A. Frison, G. Orjeda & S. Sharrock (eds). PRO*MUSA*: A Global Programme for *Musa* Improvement. Proceedings of a meeting held in Gosier, Guadeloupe, March 5 and 9, 1997.

INIBAP-IPGRI/CIRAD. 1996. Descriptors for Banana (*Musa* spp.).

The following publications are available from Asia and the Pacific office:

INIBAP. 2000. R.V. Valmayor, S.H. Jamaluddin, B. Silayoi, S. Kusumo, L.D. Danh, O.C. Pascua & R.R.C. Espino. Banana cultivar names and synonyms in Southeast Asia.

INIBAP/ASPNET 1999. V.N. Roa & A.B. Molina (eds). Minutes: Eighth meeting of INIBAP/ASPNET Regional Advisory Committee (RAC) hosted by the Queensland Horticulture Institute (DPI) in Brisbane, Australia, 21-23 October 1998.

INIBAP/ASPNET 1998. Minutes: Seventh meeting of INIBAP/ASPNET Regional Advisory Committee (RAC) hosted by the Vietnam Agricultural Science Institute (VASI) in Hanoi, Vietnam, 21-23 October 1997.

INIBAP/ASPNET 1997. V. N. Roa & R. V. Valmayor (eds). Minutes: Sixth meeting of INIBAP/ASPNET Regional Advisory Committee (RAC) hosted by National Research Center on Banana (ICAR) in Tiruchirapalli, India, 26-28 September 1996.

INIBAP/ASPNET 1996. R. V. Valmayor, V. N. Roa & V. F. Cabangbang (eds). Regional Information System for Banana and Plantain - Asia and the Pacific (RISBAP): Proceedings of a consultation/workshop held at Los Baños, Philippines, 1-3 April 1996. (ASPNET Book Series No. 6).

Contents

What is PRO*MUSA?*

The Global Programme for *Musa* Improvement (PRO*MUSA*) is a broad based programme which aims at involving all the major players in *Musa* improvement. It was developed as a means to link the work carried out towards addressing the problems of export banana producers, with those initiatives directed towards improving banana and plantain production at the subsistence and smallholder level. The global programme builds upon existing achievements and is based upon ongoing research initiatives. PRO*MUSA* is therefore a mechanism to further maximize the outputs and accelerate the impact of the overall *Musa* improvement effort. The programme is an innovative mechanism to bring together research carried out both within and outside the CGIAR, creating new partnerships between National Agricultural Research Systems (NARS) and research institutes in both developing and developed countries. The formation of such partnerships will also contribute to strengthening the capacity of NARS to conduct *Musa*-related research.
The major thrust of PRO*MUSA* is to develop a wide range of improved banana varieties from which growers worldwide can select those most suited to their needs. The programme brings together conventional breeding based on hybridization techniques with genetic engineering and biotechnological breeding approaches. This broad-based genetic improvement effort is supported by research being carried out on specific pests and diseases within the various PRO*MUSA* working groups. An efficient mechanism for evaluating new varieties produced within the framework of PRO*MUSA* is also an essential component of the programme.

A global Programme for *Musa* Improvement

3rd global meeting of PRO*MUSA*, Bangkok, Thailand,

06-08 November, 2000

The second global meeting of PRO*MUSA* was held in Douala, Cameroon, in November 1998. The meeting was attended by 70 researchers and consisted of a plenary session, followed by individual working group meetings. The report of this meeting was published in the PRO*MUSA* section of INFO*MUSA* Vol 7, No. 2.

The third global meeting should allow a further step forward to be made in the improvement of banana and plantain production at the subsistence and smallholder level.

Programme

Monday 06 November, 2000:
Inauguration of the meeting
Introduction
Plenary session
Report of the chairpersons of the working groups:
- Genetic improvement working group,
- Sigatoka working group,
- Nematology working group,
- Fusarium working group,
- Virology working group.

Introduction to the different workshops

Tuesday 07 November, 2000
Steering Committee meeting
Workshops
- "Towards a strategy for the development of new hybrids resistant to nematodes" which includes both classical breeding and biotechnology.
- "BSV in germplasm improvement and exchange"

Wednesday 08 November 2000:
Plenary session
Reports from the different workshops
Report from the Steering Committee
Aspect of the functioning of PROMUSA
Visit to Banana exposition (tentative)

Thursday 09 November 2000
Departure of participants

Participation

Participation in the meeting is limited to PRO*MUSA* participants only. Non-participants in PRO*MUSA* who have an interest in attending the meeting are invited to contact the Meeting Secretariat at the address below:

Meeting Secretariat
Jean-Vincent Escalant
INIBAP
Parc Scientifique Agropolis II
34397 Montpellier, France
Tel: + 33 4 67 61 13 02
Fax: + 33 4 67 61 03 34
e-mail: j.escalant@cgiar.org
http://www.inibap.org/promusameeting/promusameeting.htm

2nd International symposium on the molecular and cellular biology of banana, Byron Bay, Australia, 29 October-3 November 2000

First annoucement

The inaugural Symposium on the Molecular and Cellular Biology of Banana was held in March 1999 in Ithaca, New York and was a great success drawing participants from diverse backgrounds reflecting the extent to which molecular biology can be utilised in modern agriculture.

The programme includes: Welcome reception, presentation of oral papers and posters sessions, tour of banana field trials, conference dinner

The themes covered by the symposium will be:

- Genomics,
- Gene expression in transgenic plants,
- Plant pathology and disease resistance,
- Biodiversity and evolution,
- Biochemistry and fruit ripening,
- Intellectual property and genetically modified organisms.

To receive the **registration** booklet, please contact:

Ms Di O'Rourke, Banana symposium, Faculty of science, Queensland University of Technology, GPO Box 2434, Brisbane, Qld, 4001, Australia, Fax: 61 7 3864 5100

You could also visit the web site: http://www.inibap.org/byronbay/Byronbay. html

Publications

In the framework of the Nematology working group of PRO*MUSA*, research on nematode resistance screening has been carried out and three papers will be published as PRO*MUSA* research.

1) **Host plant response of banana (*Musa* spp.) cultivars from Southeast Asia to nematodes** by R. Stoffelen, Vu Thi Thanh Tam, R. L. Swennen and D. De Waele, International Journal of Nematology 9(2): 130-136.

Abstract. Thirteen *Musa* genotypes commonly grown in Malaysia and Vietnam were evaluated for their resistance to *Radopholus similis*, *Pratylenchus coffeae* and *Meloidogyne* spp. The nematode - host plant response was compared with the susceptible cultivars 'Grande Naine' and 'Cavendish 901'. *In vitro* propagated plantlets were potted in loamy sand in the greenhouse and inoculated with approximately 1000 lesion-nematodes or 2500-5000 root-knot juveniles at 4 weeks after planting. Reproduction of the nematodes was determined at 8 or 10 weeks after inoculation depending of the species. All Malayasian and Vietnamese cultivars screened were at least as susceptible to *R. similis, P. coffeae* and *Meloidogyne* spp. as the susceptible reference cultivars. Differences in susceptibility between cultivars were observed.

2) **Host plant response of Fusarium wilt resistant *Musa* genotypes to *Radopholus similis* and *Pratylenchus cofffeae*** by R. Stoffelen, R. Verlinden, J. Pinochet, R. L. Swennen and D. De Waele. International Journal of Pest Management (accepted).

Abstract. Ten *Musa* genotypes which were accepted by the International *Musa* Testing Programme (IMTP) to be resistant or moderately resistant to Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* and three Fusarium wilt susceptible cultivars were evaluated for their resistance to *Radopholus similis* and *Pratylenchus coffeae* and their nematode - host plant response compared with the susceptible cultivar 'Grande Naine'. *In vitro* propagated plantlets were transferred to the greenhouse in loamy sand in pots and inoculated with approximately 1000 nematodes at 4 weeks after planting. Reproduction of *R. similis* and *P. coffe*ae in the roots was determined at respectively 8 and 10 weeks after inoculation. The 'Pisang Jari Buaya' accessions ITC0312 and ITC0690, and 'Yangambi km5' were resistant *to R. similis*. 'Pisang Lilin', 'Bluggoe', 'Saba', 'Gros Michel', 'Williams', 'GCTCV 215', 'GCTCV 119', 'FHIA-01', 'PA 03.22', 'PA 03.44' were as susceptible to *R. similis* as 'Grande Naine'. None of the 14 genotypes evaluated were resistant to *P. coffeae*.

3) **In-Field behaviour of banana plants (*Musa* AA sp.) obtained after regeneration of cryopreserved embryogenic cell suspensions** by F.X. Côte, O. Goue, R. Domergue, B. Panis and C. Jenny. CryoLetters 21: 19-24

Abstract. This study describes the in-field behaviour of bananas (*Musa* AA sp.) obtained after regeneration of cryopreserved embryogenic cell suspensions. Observations were focused on the classical vegetal development descriptors. We observed no significant differences between the cryopreserved-derived plants and the control plants with respect to the plant height and circumference, the number of leaves, the number of fruits, the fruit length, the fruit diameter and weight, the bunch weight and the date of harvest. During the first culture cycle, 2 out of 11 descriptors analysed were however found to be different between the control and the cryopreserved suspensions derived plants. These were the numbers of nodal clusters of the inflorescence (usually called 'hands') and the date of flowering. These differences were, however, quite minor as the two cases together amounted to only 2% of the control value. During the second cycle of culture, no significant difference between the two groups of plants was found whatever the parameter analysed. These results suggest that, with the experimental conditions of the study, there is no difference at the agronomic level between plants produced from cryopreserved embryogenic cell suspensions and control plants.

Banana genomics initiative

Report of a meeting held on 6-8 April 2000 in Montpellier France, within the framework of PROM*USA*

Introduction

Modern crop improvement is based on molecular marker assisted selection and introgression of agronomic traits of interest, such as pest resis-

tance or quality. Various ongoing research projects have allowed genetic maps to be constructed, genes to be cloned, expression assays to be performed, promotors to be tested and gene constructs to be transferred into cultivars.

Though still in its infancy, the results of functional genomics of model plants will increase the understanding of basic plant biology as well as the exploitation of genomic information for crop improvement. For the identification of gene functions of a whole organism, functional genomics technology now focuses on *high throughput* (HTP) methods:

- Insertion mutant isolation,
- Gene chips or microarrays,
- Proteomics.

All these and many more HTP techniques in gene function analysis offer new uses for genes that are discovered by sequencing.

The creation of tools to study the genome, the transcriptome itself, will make a major contribution towards rapid progress in *Musa* improvement. BAC, EST and cDNA libraries, micro/macro arrays and DNA-chips as well as maps (genetic, cytogenetic and physical) and expression charts will foster the development of *Musa* genomics in the same way that molecular markers profited from the refinement of *Musa* genetics.

Plant genomics is a newly emerging field that holds the promise of describing an entire genetic repertoire of plants. The information derived from studies of plant genomics will help us understand how genes enable a plant to carry out its functions as a living organism, and how the diversity of functions in all plants are related to simple changes in individual genomes. Plant genomics ultimately may be used to genetically modify plants for optimal performance in different biological, ecological and cultural environments for the benefit of humans and the environment.

In order to make rapid progress in genomics research as applied to *Musa*, a meeting was organized in the framework of PRO*MUSA*, bringing together the main research teams working in this area.

Toward the end of the meeting a remarkable degree of consensus for the Banana Genomics initiative was reached. All the parties agreed to form a Banana Genomic consortium. PRO*MUSA* therefore provides a strong opportunity for this consortium to become a leader in banana genomics research through the development and implementation of a visionary strategy that cuts across different institutions around the world.

How the consortium will take advantage of existing strengths

Deciphering the banana genome is an enormous task that will require participation and collaboration of scientists around the world. The Banana Genomics Consortium will bring together and enhance combined expertise (from both the public and private sector).

The development of a banana genomics strategy and inter-institutional and inter-disciplinary interaction in the design of experiments, the interpretation of data, and the formulation of project proposals will greatly enhance the global efforts in this area of genomics.

The Global Programme for *Musa* Improvement (PRO*MUSA*) offers a good framework to assume worldwide leadership in the new initiative on banana genomics, whose activities will be developed within the Banana Genomics Consortium. PRO*MUSA* is a broad-based programme that aims at involving all the major players in *Musa* improvement. The major thrust of PRO*MUSA* is to develop a wide range of improved *Musa* varieties, bringing together conventional breeding and biotechnology supported by research that is carried out on pests and diseases within the various working groups.

Objectives

To assure the sustainability of the banana as a staple food crop for a large part of the world's population and its ever-changing food needs, and progressively restrictive environments. This can be achieved through an integrated genetic and genomic understanding which can allow targeted breeding and transgenic strategies.

To use post genomics technologies to better tap the bio-diversity in order to improve local bananas for the benefit of the smallholder farmer.

Modus operandi

The consortium will operate under the guidance of a scientific committee within PRO*MUSA*.

Criteria for membership to the consortium will be based on:

- High level of expertise (scientific publications),
- Facilities,
- Commitment to abide by the rules of the consortium.

This will be elected through an open consultation within the Scientific Committee with a 2/3 majority.

Composition and role of the Scientific Committee

Dr Françoise Carreel, CIRAD-FLHOR, Montpellier, France
Prof. James Dale, QUT, Brisbane, Australia
Dr. Jaroslav Dolezel, IEB, Olomouc, Czech Republic
Prof. Peter Gresshoff, Queensland University, Brisbane, Australia
Dr. Pat Heslop-Harrison, John Innes Center, Colney, United Kingdom
Dr. Dieter Kaemmer, University of Frankfurt, Frankfurt, Germany
Dr. Pierre Lagoda, CIRAD-BIOTROP, Montpellier, France
Dr. Michael Pillay, IITA, Nigeria
Dr. Lazlo Sagi, KUL, Leuven, Belgium.

Each member of the committee will be responsible for arranging a temporary or permanent replacement from the represented group when appropriate. New members will be invited to join the Scientific Committee based on a nomination from one member of the committee and an affirmative vote by

a majority. It is anticipated that the committee will maintain regular communication and will meet annually, taking advantage of PROM*USA* facilities whenever possible.

It was agreed upon that the role of the Scientific Committee is to provide an oversight and direction to the consortium. This committee will also be responsible for the setting up of the programme priorities, based on an open discussion with the group.

Rules of the consortium

People participating in the consortium (members) shall agree:

- To share within the group all the information obtained from a project funded through the consortium. Information will be freely available to all the members.
- The consortium will negotiate access to enabling technologies with the private sector.
- To share materials which are relevant to the development of enabling technologies.
- To facilitate access to infrastructure within the consortium.
  (Materials: these include clones, libraries, and sequence information as well as protocols, methods and preprints, plant material, tissue samples, DNA probes. Co-authorships should be pre-arranged to secure joint ownership of technology.)

How genomics can benefit the improvement of banana

Several research institutions, universities, and private companies are now involved in the improvement of both dessert and cooking bananas by conventional breeding and, increasingly, by genetic engineering. The classical breeding strategy involves crossing a fertile diploid accession onto good edible triploid cultivars in order to create tetraploid hybrids. Another strategy aims at "reconstructing" triploid cultivars by crossing improved diploids onto artificially doubled-diploids (autotetraploids).

This breeding effort could be considerably strengthened and accelerated by a better knowledge of the genome at molecular and chromosomal levels.

A very important problem for breeding and genetic analysis is the variability of chromosome structure between different accessions due to structural rearrangements. Translocations and inversions of segments of chromosomes lead to important meiosis irregularities and irregular chromosome transmission. Genes usually segregating independently will show in that case variable degrees of linkage in the progenies of structural hybrids. The overall effect of this structural hybridity interferes with the breeders' efforts at recombining and transferring desirable traits from wild and cultivated diploids to new improved hybrids.

It is highly necessary to develop new molecular tools that will allow the location of important genes for traits such as pest and disease resistance, and crop quality, as well as to enhance the knowledge on the inheritance mechanisms of these traits. Molecular cytogenetic techniques involving *in situ* hybridisation of DNA sequences have proven to be a valuable method in gaining insight to the genome. Fluorescence *in situ* hybridisation (FISH) with multiple probes has been shown to be an efficient method for the study of fundamental aspects of chromosome structure and behaviour. Genomic *in situ* hybridisation (GISH) allows differentiating chromosomes from different genomes in the same species, enabling the identification of parental chromosomes in interspecific hybrids. Because *Musa* chromosomes are usually not entirely labelled following GISH, it is important to develop more molecular cytogenetic landmarks that will contribute to the construction of physical maps and permit integration of genetic and physical maps including the analysis by FISH of the 18S-5.8S-25S and 5S rDNA sequences as well as the telomeric sequences.

Genetic transformation of bananas may also highly contribute to the creation of new clones resistant to pests and diseases. However, even if genetic transformation protocols have been successfully developed in different institutions, allowing to regenerate transformed banana plants with antifungal protein genes, and anti-viral genes, specific banana genes and promotors are also needed.

Different approaches for discovering gene sequences and functions can be pursued, each with specific advantages and shortcomings: the expressed genes of a plant can be catalogued by sequencing *expressed sequence tags* (ESTs) or *complementary DNA* (cDNA). There are more than 100,000 plant ESTs available in public databases, which offers an efficient method for gene discovery in plants. A comparison of EST databases from different plants, tissues and conditions reveals the diversity in coding sequences between plants. At the same time, however, it provides a global perspective of the similarities in genes for specific processes, such as ripening conditions, or the induction of pathogens. A sequence similarity analysis using bioinformatics tools permits the assignment of probable gene function and the identification of genes that are similar between species.